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Fate of fertilizer nitrogen in a subarctic agricultural soil

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FATE OF FERTILIZER NITROGEN IN A

SUBARCTIC AGRICULTURAL SOIL

A

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FATE OF FERTILIZER NITROGEN IN A

SUBARCTIC AGRICULTURAL SOIL

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ABSTRACT

A nitrogen balance approach was taken to determine the fate of fertilizer nitrogen in a subarctic agricultural soil. Urea and calcium nitrate fertilizers were compared in a three-year spring barley recrop field study. Methods of N application included incorporating the N fertilizer into the soil during spring tillage versus broadcasting it on the soil surface after planting. ^{15}N labeled urea was applied on one-meter square subplots within the main fertilizer plots. Nitrogen transformations and movement were monitored with ammonia volatilization traps, suction cup lysimeters, deep soil cores, plant tissue samples, and grain samples. Environmental data including precipitation, soil temperatures and soil moisture tensions were collected.

Fertilizer N loss by ammonia volatilization was negligible, amounting to only a few grams N/ha/day. Rate of urea hydrolysis was rapid in the cool soil and was not considered to be a limiting factor affecting N availability to the crop. There appeared to be a little nitrate leaching during the growing season, but some may have occurred between cropping seasons. Only 16 percent of the fertilizer N could not be detected when the crop was physiologically mature, and that loss was accredited mostly to denitrification.

Fertilizer N use efficiency, determined by the Difference Method, was 73 and 60 percent for calcium nitrate and urea, respectively. When the crop was physiologically mature, average fertilizer N recovery rates determined by the Isotope Dilution Method were: 40 percent in the plants, 43 percent immobilized in the soil, 1 percent available in the soil, and 16 percent unrecovered.

Barley yields were not significantly affected by N source, but plants took up more N where nitrate had been applied. Position of N placement had little effect on either N loss or barley yield, but the surface application of N resulted in delayed barley maturity when spring rains were deficient.

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF TABLES

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INTRODUCTION

Alaskan farmers applied over 3,000 tons of nitrogen to their soils in 1985 (Brown *et al.*, 1986). Although this figure may seem small compared to the nitrogen fertilizer consumption of 'agricultural' states, it represents a major cost to producers in Alaska's fledgling agricultural industry, and it represents a possible source of pollution to Alaska's ground- and surface-water supplies.

Little is known about the fate of nitrogen fertilizers in interior subarctic agricultural soils. Most Scandinavian studies pertain to a coastal climate much warmer than that of interior Alaska, and very little relevant information is available from northern areas of the Soviet Union. Several nitrogen cycling studies in Alaska have been conducted in tundra and forest ecosystems (Van Cleve and Noonan, 1975; Van Cleve and Alexander, 1981; Van Cleve *et al.*, 1981; Van Cleve and Oliver, 1982; Flanagan and Van Cleve, 1983; Van Cleve *et al.*, 1983). However, the environmental conditions in these ecosystems differ greatly from those in an agricultural field. Nitrogen studies associated with Alaskan agriculture have concentrated primarily on soil test calibrations for newly cleared lands (Michaelson *et al.*, 1982) and the effects of nitrogen materials, rates and placement on potatoes (Laughlin, 1971a & 1971b) and grasses

(Klebesadal, 1970; Laughlin, 1963; Laughlin *et al.*, 1971, 1973, 1976 & 1987; Mitchell *et al.*, 1983). Recommended fertilizer rates and application methods have been determined chiefly by 'fertilizer trials' comparing various treatments to determine which one results in the greatest crop response. If 50 to 100 kilograms of nitrogen per hectare has been applied to the soil, and the harvested crop contains a similar quantity of nitrogen, it is often assumed that the fertilizer use efficiency was good and that fertilizer nitrogen losses were negligible. This assumption is not necessarily valid when one realizes that the plow layer of a cultivated soil in interior Alaska contains, on the average, about 4,500 kg/ha of total soil nitrogen (Mitchell and Offner, 1982). Most of this soil nitrogen is combined in organic compounds in varying degrees of complexity and is unavailable for plant use. However, this reservoir of soil nitrogen is dynamic and is constantly undergoing chemical and biological changes. Of the total nitrogen in the root zone, less than two percent is usually available for plant use at any one time (Brady, 1985). The types of nitrogen transformations and the rates at which they occur in the soil are controlled by many chemical and environmental factors.

Many questions need to be answered concerning transformations of nitrogen fertilizers in subarctic soils. Do nitrogen fertilizers respond the same in cool subarctic soils as they do in warmer soils? How rapidly does fertilizer nitrogen change from one chemical form to another in the soil? Is fertilizer nitrogen in a form available for plant uptake when the plant needs it? What percentage of fertilizer nitrogen is actually used by the crop and how much becomes immobilized and held in a form unavailable for plant use? How much is lost through leaching, denitrification or ammonia volatilization? These questions and many others need to be answered before fertilization practices can be fine-tuned to the extent that fertilizer use efficiency is maximized and nitrogen losses are minimized.

The principal nitrogen fertilizer used in Alaska is dry crystalline urea [$CO(NH_2)_2$]. This is due, primarily, to three factors: a) dry urea does not require the specialized storage and handling equipment that is needed for liquid and gaseous fertilizers, b) it has a higher nitrogen analysis than other dry nitrogen fertilizers, and thus, transportation and application costs are less per unit of nitrogen than for other dry fertilizers, and c) it is currently manufactured near Kenai, Alaska and is the only dry nitrogen fertilizer produced in the state.

Although urea is less expensive than other nitrogen sources in Alaska, crop responses from applications of urea have sometimes been reported to be slower and inferior to crop responses from equal applications of nitrogen in the ammonium and nitrate forms (Laughlin, 1963; Mitchell and Offner, 1982). This is not unusual, however, since numerous studies have shown responses from urea applications to be less than from other N sources, particularly where the urea had been applied on the soil surface (Therman, 1979; Freney *et al.*, 1983). The difference is usually attributed to volatilization loss of nitrogen as ammonia (NH_3) under conditions of high soil pH, high air and soil temperatures, and high evaporative losses of soil moisture (Therman, 1979). Figure 1 outlines possible nitrogen transformation pathways in the soil from a urea fertilizer source.

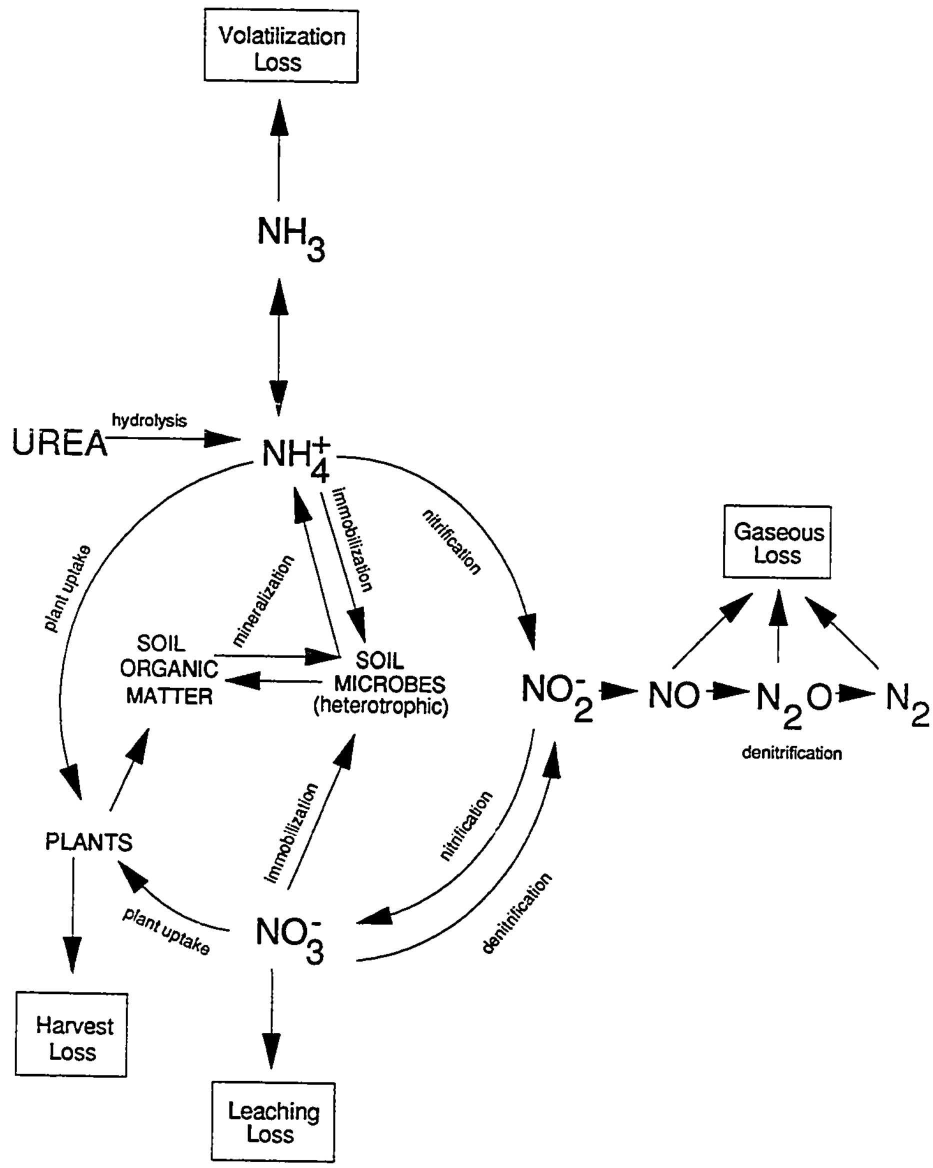

Figure 1. Possible fate of urea in soil.

OBJECTIVES

The overall objective of this study was to gain a better understanding of the behavior of fertilizer nitrogen in agricultural soils in interior Alaska. The specific goals of the research were to:

1. Estimate gaseous loss of N from the soil (i.e., ammonia volatilization and denitrification) following the application of two N sources.

2. Determine nitrate leaching losses, and hence, potential pollution of ground water from urea and nitrate fertilizers.

3. Measure crop uptake and determine efficiency of fertilizer nitrogen utilization.

4. Determine net seasonal immobilization and mineralization of nitrogen in a field soil.

LITERATURE REVIEW

Urea Hydrolysis and Ammonia Volatilization

Urea is very soluble in water (78 g/100 mL at 5°C) and is only weakly absorbed by soil organic matter (Chin and Kroontje, 1962). Therefore, urea may be susceptible to leaching if heavy rainfall or irrigation is received by the soil immediately after application. Urea moves through soil more rapidly than nitrate, but still slightly behind the wetting front (Fenn and Miyamoto, 1981). In most soils, urea undergoes rapid biological hydrolysis (catalyzed by the enzyme, urease) to ammonium carbonate $[(NH_4)_2CO_3 \cdot H_2O]$ which further decomposes to ammonium (NH_4^+) and carbon dioxide (CO_2) by Eq. [1] and [2] listed below (Fenn and Kissel, 1973):

[1] $$CO(NH_2)_2 + 3H_2O \xrightarrow[\text{enzyme}]{\text{urease}} (NH_4)_2CO_3 \cdot H_2O$$

[2] $$(NH_4)_2CO_3 \cdot H_2O + 2H^+ \rightarrow 2NH_4^+ + CO_2 + 2H_2O$$

Although all soils seem to contain urease, its activity varies from soil to soil. Numerous papers have been published on factors affecting urea hydrolysis, and comprehensive summaries have been published by Bremner and Mulvaney (1978), Mulvaney and Bremner (1981), and Ladd and Jackson (1982). Urease activity, and thus the rate of hydrolysis of urea has been positively correlated to several soil properties, e.g., urea concentration, soil moisture, temperature, pH, drying and rewetting, organic materials, and other factors (Mulvaney and Bremner, 1981).

Mitchell and Offner (1982) measured rates of urea hydrolysis in four Alaskan soils incubated at 8 and 16°C and found that the conversion of urea N·to ammonium N proceeded very rapidly in each soil. At the lower temperature, urea hydrolysis was 50 percent complete in each soil within 24 hours, and was essentially complete by the third day following application. In a subsequent field study, they found only a trace of urea in the soil four days after application. These results are similar to those found on California soils at similar temperatures (Broadbent *et al.*, 1958). Gordon (1986) mixed urea with soil and litter from an Alaskan forest floor and incubated these samples at 25°C. Although he did not monitor the rate of urea depletion, he found that levels of ammonium N peaked on the second day, indicating rapid urea hydrolysis.

The formation of ammonium carbonate in Eq. [1] has been shown to raise the pH of the soil in the vicinity of the fertilizer crystal to approximately 9.2 in both acid and calcareous soils (Fenn *et al.*, 1981). Whenever the soil pH gets above 7, the reactions described in Eq. [3] and [4] may occur instead of that described in Eq. [2].

[3] $$(NH_4)_2CO_3 \cdot H_2O \rightarrow 2NH_4OH + CO_2$$

[4] $$NH_4^+ + OH^- \Leftrightarrow NH_4OH \Leftrightarrow NH_3 + H_2O$$

The resulting ammonia loss by volatilization is especially likely when urea fertilizer is spread on or near the soil surface (Fenn and Kissel, 1973). Ammonium ions on the soil surface may not be readily attracted to exchange sites on soil particles, and evaporation following hydrolysis may result in the simultaneous loss of water and ammonia (Fenn and Kissel, 1976). Factors affecting ammonia volatilization include: source of ammonia, ammonium-ammonia equilibrium, solution pH, buffering capacity of the soil, the presence of calcium carbonate, temperature, water loss, effect of plants, and other factors. Recent reviews of research involving ammonia volatilization have been published by Freney *et al.* (1981) and Nelson (1982).

Nitrification

Nitrification is the aerobic biochemical process whereby NH_4^+ is oxidized to NO_2^- and then subsequently to NO_3^- by nitrifying bacteria. In the first step, the valence of nitrogen changes from -3 in NH_4^+ to +3 in NO_2^- suggesting the possibility of two or more intermediates in this reaction. Hydroxylamine (NH_2OH) and nitroxyl (NOH) have been suggested as probable intermediates (Nicholas, 1978). However, these compounds are relatively unstable and there is very little evidence supporting their existence in the soil.

The only microorganisms linked directly to nitrification in natural environments at the present time are the Gram-negative chemoautotrophic nitrifying bacteria comprising the family Nitrobacteriaceae. Several genera of NH_4^+ oxidizers have been isolated from soil. However, due to difficulties in isolating these chemoautotrophic bacteria in pure cultures, most biochemical studies have been limited to Nitrosomonas and Nitrobacter. Although other bacteria are likely involved in and may even predominate over soil nitrification reactions, the oxidation of NH_4^+ to NO_2^- and subsequently to NO_3^- has commonly been attributed to Nitrosomonas and Nitrobacter, respectively, largely as a result of the inadequacy of available methodology (Schmidt, 1982).

Some heterotrophic microorganisms have been isolated from the soil and cultured under conditions that have led to the formation of NO_2^- and NO_3^-. However, there is no direct evidence that such reactions are important in nature, and if heterotrophic nitrification does occur in nature, it is considered secondary to autotrophic nitrification (Focht and Verstraete, 1977). Recent studies have shown nitrification occurring under extremely acid conditions (pH 4.5 or lower) and at high temperatures (50 to 60°C); conditions considered out of the range autotrophic nitrification. In these environments, circumstantial evidence suggests heterotrophic nitrification. However, unequivocal evidence relating the occurrence of a particular heterotroph in its natural environment to the progression of nitrification in that environment has yet to be provided (Haynes, 1986).

The main factors which limit nitrification in soil are the availability of substrate NH_4^+, low concentrations of O_2, low concentrations of CO_2, high and low pH, and low temperature. These factors were discussed extensively by Focht and Verstraete (1977) for nitrifying microorganisms both in culture and in natural and N-enriched soils. Oxygen and CO_2 are most likely to be limiting in very wet soils, at very high soil temperatures, or in organic soils with very high total microbial activity (Schmidt, 1982). Thus, in a well drained, fertilized, subarctic, agricultural soil, temperature and pH would appear to be the variables most likely to limit the rate of nitrification during the growing season.

It is usually reported that cold and wet soils are essentially inactive with respect to nitrification (Schmidt, 1982). Anderson and Boswell (1964) reported little or no nitrification until the soil warmed up to 4 or 5°C. More recently, Malhi and Nyborg (1979) reported considerable nitrification of urea fertilizer in an agricultural soil when temperatures were below or very near freezing. The optimum temperature for nitrification appears to vary widely among soils. Mahendrappa *et al.* (1966) reported maximum nitrification rates at 20-25°C for a group of soils from the northwestern United States and at 30-40°C for soils of the southwestern United States. Anderson *et al.* (1971) reported that nitrification proceeded rapidly at 30°C in almost all soils tested, but found considerable differences between soils at cooler temperatures near 6°C. They suggested that the activity of the soil nitrifying flora is a function of the metabolic adaptation of the organisms to the climate of origin. Numerous researchers have reported significant increases in nitrifier numbers and activity with slight temperature increases in the range of 8 to 20°C (Fredrick, 1957; Parker and Larson, 1962; and Sabey *et al.* 1956 and 1959). Malhi and McGill (1982) found the optimum temperature for nitrification in an agricultural soil in central Alberta to be 20°C.

Concerning soil acidity, most observations indicate an arbitrary lower limit for nitrification of pH 4.0, obvious nitrification in the pH range of 4 to 6, and pH independent nitrification in the range of 6 to 8 (Schmidt, 1982). However, nitrification often occurs in the soil at pH ranges far below the pH limits observed for nitrifying bacteria in pure culture. One must remember that soil pH is an average value, and that any given soil may contain microsites ranging from alkaline to very acid. Focht and Verstraete (1977) suggested that nitrification under extremely acid conditions may be the result of heterotrophic nitrification.

Much controversy in the literature deals with allelochemical inhibition of nitrification by climax vegetation. Some researchers believe that phenolic compounds or thiourea analogues released by climax vegetation inhibit nitrification (Lodhi, 1976, 1978; Rice, 1984; Rice and Pancholy, 1972; Wheeler and Donaldson, 1983). Others argue that low quantities of NO_3^- in soils under climax vegetation can be explained in terms of chemical balances and environmental conditions such as: ammonium availability, soil pH, plant uptake, etc. (Brar and Giddens, 1968). Mitchell and Offner (1982) suggested that nitrification inhibitors produced by decomposing forest litter may increase ammonia volatilization losses and, thus, account for poor urea performance on some newly cleared soils in interior Alaska. They cited reports by Bundy and Bremner (1974) which showed that ammonia losses to the atmosphere from urea sources have been greatly increased by artificial nitrification inhibitors causing high concentrations of NH_4^+ to accumulate in the soil. Mitchell and Offner (1982) showed considerable differences in rates of nitrification in incubated soils from geographically divergent locations in Alaska. It is interesting to note, that among the soils they tested, the soil with the lowest pH (4.9) displayed the highest rate of nitrification. It was also their only soil which was formed under permanent grassland vegetation, and thus, did not contain any forest residues, possibly adding credence to their hypothesis concerning allelochemical inhibition of nitrification. Conversely, several workers have reported an inhibition of nitrification in grassland soils; others express doubt. In a review of these studies, Clark and Paul (1970) pointed out that the bulk of the evidence indicates that nitrification inhibition does occur in grassland soils but that the subject is in need of further study.

Nitrogen Mineralization-Immobilization

Mineralization refers to the microbial transformation of organic nitrogen compounds to inorganic nitrogen. Immobilization is the converse in that microorganisms convert inorganic nitrogen (ammonium and nitrate) to organic forms. Plant uptake and assimilation of inorganic nitrogen compounds is a variant of the immobilization process but, in describing soil nitrogen, immobilization is normally restricted to the assimilation of inorganic nitrogen by soil microflora (Jansson, 1971). Mineralization and immobilization proceed continuously and concurrently in the soil. The driving forces of these two reactions are the heterotrophic microflora, and their energy source is the carbon compounds in the soil organic matter or input carbon sources in the form of crop residues, animal manures, and their by-products. During the decomposition process, energy is released, carbon is lost as carbon dioxide, and nitrogen is mineralized to the inorganic nitrogen pool which is available for other processes such as immobilization, nitrification, denitrification, or plant uptake. The rates at which nitrogen mineralization and immobilization proceed are influenced by the nitrogen content and composition of the organic material undergoing decomposition, and soil environmental factors, such as: moisture, temperature, aeration, pH, and inorganic nutrient supply.

Carbon to nitrogen ratios (C:N) have traditionally been used as an indication of whether mineralization or immobilization predominates in the soil. It is often assumed that if the C:N ratio is less than 20, net mineralization will occur; between 20 and 30, mineralization and immobilization will be approximately equal; and greater than 30, net immobilization will occur (Tanji, 1982). Many exceptions have been reported in the literature, and net mineralization of N can occur at C:N ratios as high as 40 to 50 if the organic matter contains large quantities of compounds resistant to decomposition, such as, lignin and cellulose (Frissel and van Veen, 1978). As Jansson and

Persson (1982) point out, the C:N ratio is merely an approximation of the really important parameter, the E:N ratio, where E represents the energy available for release in the process of mineralization. Since all organic compounds are not equally susceptible to decomposition, one must keep in mind that C:N ratios can be misleading. In spite of this limitation, C:N ratios have found widespread acceptance in the literature as indicators of potential mineralization and immobilization.

Denitrification

Denitrification is a major process by which fixed nitrogen is lost from the soil to the atmosphere. The *SSSA Glossary of Soil Science Terms* (1979) defines denitrification as "the microbial reduction of nitrate or nitrite to gaseous nitrogen either as molecular nitrogen or as an oxide of nitrogen." Denitrification is usually described as an anaerobic respiratory process carried out by a limited number of bacterial genera. In this process, N oxides serve as terminal electron acceptors for respiratory electron transport leading from "reduced" electron donating substrate through numerous electron carriers to a more oxidized N oxide (Firestone, 1982). During this process, energy is conserved by electron transport phosphorylation.

The general requirements for denitrification are (i) the presence of bacteria possessing the metabolic capacity; (ii) suitable electron donors such as organic C compounds, reduced S compounds, or molecular hydrogen, H_2; (iii) anaerobic conditions or restricted O_2 availability; and (iv) N oxides, NO_3^-, NO_2^-, NO, or N_2O as terminal electron acceptors (Firestone, 1982). In soil, the main factors that affect denitrification are (i) soil particle size, density, and structure as they relate to moisture and gaseous flux in the soil; (ii) biological oxygen demand as affected by quantity of decomposable organic matter; (iii) pH; and (iv) temperature (Broadbent and Clark, 1965). Most denitrifying bacteria are chemoheterotrophs and are aerobic organisms capable of anaerobic growth only in the presence of N oxides in low oxygen environments (Firestone, 1982). Oxygen represses the synthesis of dissimilatory nitrate reductase, the enzyme responsible for the reduction of nitrate to nitrite (Focht and Verstraete, 1977). High rates of denitrification often coincide with high soil moisture content since the oxygen diffusion rate is considerably slower in wet soil. Also, high soil moisture stimulates microbial activity which in turn increases oxygen demand. Ryden and Lund (1980) reported peak denitrification rates in the field at soil moisture tensions of 5-10 kPa which agreed closely with that (0-35 kPa) reported by Pilot and Patrick (1972) in laboratory studies. Sometimes, however, highly variable rates of denitrification are measured in fairly close proximity in a well aerated soil. The source of this variability is usually explained as anaerobic microsites in the soil, such as in the centers of saturated soil aggregates (Firestone, 1982). In investigating soil microsites as a source of denitrification variability, Parkin (1987) found that "hot-spots" of denitrification activity in the soil were associated with particulate organic C material in the soil. Although he agreed that soil conditions such as temperature or moisture content may determine when denitrification peaks at these "hot-spots", his research indicates that location of the denitrifying microsites is determined by the presence of organic C.

Most researchers have reported denitrification to be affected very little by pH in the neutral range (6-8), to be very low at pH 3.5, and rapidly increasing in magnitude between pH 3.5 and 6.5 (Firestone, 1982). Although denitrification activity has often been found to increase exponentially with increasing temperature within the range of enzymatic activity above 15°C, the relationships are more complex at lower temperatures (Firestone, 1982). Craswell (1978) reported a strong interaction between soil temperature and soil water content. He found no detectable denitrification at 10°C in even the wettest soil conditions (-10 kPa). Cho *et al.* (1979), studying soils at 100 percent moisture content, reported a threshold temperature for denitrification at 2.75°C and a linear relationship between temperature and denitrification intensity up to 20°C.

Leaching

The transfer of nitrogen out of the plant rooting zone by percolating water is considered leaching loss. N-losses through leaching occur mainly as nitrate, the movement of which is closely related to water movement (Legg and Meisinger, 1982). The transported nitrogen may be retained in deeper soil layers where it may be partially available to subsequent crops, it may undergo denitrification in the deeper layers, or it may eventually move on down into underlying aquifers (Khanna, 1981).

Leaching is often the most important channel of N loss from field soils other than that accounted for by plant uptake (Allison, 1973). Major losses of N occur when two prerequisites are met: (i) soil nitrate content is high, and (ii) water movement is large (Legg and Meisinger, 1982). Geographically, N-leaching is most serious in regions where rainfall exceeds evapo-transpiration and where fertilizer management practices are inappropriate (Khanna, 1981). Nitrate leaching is least likely to take place during the summer when evapo-transpiration usually exceeds precipitation, and plant uptake rates are high (Allison, 1973).

Crop Uptake

Ammonium and nitrate are the two most common forms of N utilized by field crops. Most common crops can readily absorb either of these two forms of N and, if any preference exists, it is usually in favor of ammonium early and nitrate late in the season (Olson and Kurtz, 1982). Typically, 30 to 60 percent of applied fertilizer N is directly absorbed into the tissue of the growing crop, and in grain crops, about one-fourth to one-half of the absorbed N is returned to the soil as crop residues (Power, 1981).

Fertilizer Nitrogen Budgets

Many studies have focused on the fate of applied N and have attempted to identify the percentages that: were recovered by the crop; remained in the soil for possible use by subsequent crops; or were lost from the soil by volatilization, denitrification, leaching, or other methods. Hauck and Bremner (1976) described the four following methods for determining the recovery of applied N by plants: (i) the Difference Method, which compares the difference in N uptake from N-fertilized and unfertilized plots; (ii) the Isotope Dilution Method, in which, following the addition of an ^{15}N labeled fertilizer, total N is determined and a N isotope-ratio analysis is used to identify N from the fertilizer source; (iii) linear regression of crop N uptake where multiple rates of N have been applied; (iv) linear regression of crop ^{15}N uptake where multiple rates of ^{15}N-labeled fertilizer have been applied. Users of the Difference Method must assume that immobilization, mineralization, and other N transformations during the course of the experiment are the same for both fertilized and unfertilized plots. Users of the Isotope Dilution Method must accept three fundamental assumptions: (i) N in the natural state has a constant isotope composition; (ii) living systems discriminate between N isotopes very little, if at all; and (iii) the chemical identity of isotopes is maintained in biochemical systems i.e. ^{15}N does not convert to ^{14}N, and vice versa.

Most of the recent studies of N-fertilizer budgets have been conducted with ^{15}N-labeled fertilizer materials. Many researchers have concluded that a properly conducted ^{15}N experiment is the only correct way to study fertilizer N balances (Westerman and Kurtz, 1974; Fried *et al.*, 1975; Edwards, 1978). However, Hauck and Bremner (1978) responded that the assumptions must be recognized for each method, and much useful information can be gained from nontracer methods, depending on the questions to be answered. For example, an isotope dilution study may show the location and quantity of fertilizer N in each pool at the time of sampling but will give no indication of the amount of biological turnover that has occurred since application, i.e. transposition from one N pool to another as in immobilization and subsequent remineralization where labeled ions may replace unlabeled ions. However, the Difference Method may present a better overall picture of the crop response to the N fertilization, regardless of whether the N recovered in the crop was from the fertilizer source or merely made available as a result of the fertilizer application. Hauck and Bremner (1978) suggested that isotope dilution studies should ideally include two types of controls: plots which receive no N, and plots which receive unlabeled N at rates equivalent to those where isotopically labeled N is used. Thus, results would, in essence, be based on a combination of the Isotope Dilution and the Difference methods.

METHODS AND MATERIALS

Site Description

A study site was selected, in the spring of 1982, on a University of Alaska experiment field near Mile 1408 of the Alaska Highway (64°49'N, 147°52'W). Soil at the test site consisted of stabilized loess ranging from approximately 90 cm to two meters in depth, overlaying the coarse sand and gravel of an old outwash plain. It was classified as a nearly level Beales (*Typic Cryopsamment*) silt loam with sand content increasing with depth. A truck-mounted Giddings hydraulic soil probe was used to randomly collect ten soil cores representative of the area for baseline soil analyses. The cores were divided into depth increments of 0-15, 15-30, 30-60, 60-90, and 90-120 cm. The samples were transported in an insulated box back to the laboratory where they were oven dried at 55°C, then shipped to the soil testing laboratory in Palmer, Alaska for analyses (Table 1).

Field Procedures

Experiment design and field instrumentation

Each spring, the study area was uniformly fertilized with triple superphosphate and potassium sulfate at a rate of 30 and 45 kg/ha P and K, respectively. The main plots of the study consisted of six nitrogen fertilizer treatments replicated five times in a randomized complete block design.

Table 1. Baseline soil physical and chemical properties.

		Soil Depth (cm)				
Property†	**units**	**0-15**	**15-30**	**30-60**	**60-90**	**90-120**
pH		5.34 (0.07) *	5.73 (0.06)	6.07 (0.26)	6.38 (0.20)	6.22 (0.24)
O.M.	(kg/ha)	75,066 (8,405)	20,940 (5,933)	11,183 (2,431)	4,735 (1,473)	6,428 (754)
Total N	(kg/ha)	2,919 (369)	1,745 (161)	2,771 (272)	2,473 (95)	2,176 (66)
NH_4^+-N	(kg/ha)	8 (4)	3 (2)	4 (2)	4 (2)	6 (2)
NO_3^--N	(kg/ha)	10 (4)	3 (2)	2 (1)	4 (2)	2 (1)
P	(kg/ha)	13 (3)	8 (5)	27 (7)	40 (8)	35 (1)
K	(kg/ha)	149 (27)	65 (16)	122 (14)	121 (31)	84 (16)
B.D.	(g/cm^3)	1.05 (0.09)	1.43 (0.11)	1.60 (0.07)	1.73 (0.10)	1.62 (0.09)
Sand	(%)	36 (10)	51 (17)	69 (6)	88 (4)	90 (4)
Silt	(%)	53 (10)	38 (16)	22 (5)	7 (4)	6 (3)
Clay	(%)	11 (2)	11 (1)	9 (1)	5 (1)	4 (1)

† O.M. = organic matter by Walkley-Black procedure; Total N by Kjeldahl digestion; NH_4^+-N and NO_3^--N from 1*N* KCl extract; P extractable with Bray-1 solution; K extractable with NH_4OAc (pH 7); B.D. = bulk density of oven dry soil; sand, silt, and clay by hydrometer procedure (Michaelson *et al.*, 1987).
* Values in parenthesis indicate the standard error for the mean above.

Individual plots were ten meters square and were separated on all sides by four-meter wide alleys. The fertilizer treatments were: urea (surface), urea (incorporated), calcium nitrate (surface), calcium nitrate (incorporated), zero-N (surface), and zero-N (incorporated). Urea and calcium nitrate were both applied at a rate of 100 kg N/ha. Zero-N plots received no nitrogen fertilizer. For the incorporated treatments, the N fertilizer was mixed into approximately the top 10 cm of soil with a single pass of a tandem disk immediately after fertilization. Surface treatments were applied on the soil surface after planting. There was no difference between zero-N (surface) and zero-N (incorporated) treatments except for their separate designations to facilitate statistical analysis of the data. Treatments were repeated on the same plots each year. All plots were planted to barley cv. 'Lidal' in rows 17 cm apart with a tractor drawn grain drill. Fertilizer applications and planting were accomplished on June 3, 1982; May 20, 1983; and May 17, 1984. Following harvest each year, the plot area was cleaned off with a large combine and all loose straw was removed from the plot area to simulate an actual farm situation where straw is often baled and removed for livestock feed or bedding.

An ^{15}N microplot, one-meter square in size, was established in each of the two urea plots and in one zero-N plot in each block. The microplot area was covered with a 1-m^2 plywood tray during main plot fertilizer application. After fertilization, the location of the microplot was marked with flags, the tray with fertilizer was removed, and the microplot was hand fertilized at the same rate as the main plot but with urea containing five atom percent ^{15}N. New microplot areas were selected in the main plots each year, and the old microplots were maintained to monitor the rate of depletion of the labeled fertilizer nitrogen from the soil. The tandem disk was raised over the microplots during tillage operations and the microplots were hand-tilled with a garden hoe to prevent dilution and scattering of the ^{15}N. Each microplot received ^{15}N-labeled fertilizer only once, when it was established. In successive years, that microplot, although still hand-tilled, was fertilized the same as the rest of the main plot.

For sampling soil water below the root zone, suction cup lysimeters (Linden, 1977) were buried in the main plots. Each lysimeter consisted of a 45-cm length of polyvinyl chloride (PVC) pipe with a porous ceramic cup (100 kPa air-entry value) epoxied to the lower end. The upper end contained a neoprene stopper through which two nalgene tubes passed. The tubes extended from the bottom of the ceramic cup to the soil surface. By clamping off one tube and drawing a vacuum on the other with a vacuum pump, a vacuum could be created in the PVC chamber allowing the porous cup to draw soil water into the chamber at soil moisture tensions up to one bar. By applying pressure to one of the tubes, the water sample could be blown out through the other tube into a sample bottle. These lysimeters were installed, four per plot, two at 75-cm depth and two at 150-cm depth, in each of the three incorporated treatment plots in each block.

Along side the lysimeters in blocks 1, 3, and 5, gypsum blocks and thermisters were buried at depths of 5, 15, 50, 100, and 150 cm. These instruments had labeled electrical leads extending to the soil surface which allowed soil moisture tension at each depth to be read with a voltage meter and soil temperature at each depth to be read with a hand-held tele-thermometer.

All instrumentation was installed the first year of the study, prior to planting. All instruments were left in place for the duration of the study except for the thermisters and gypsum blocks at the 5- and 15-cm depths which were removed during spring tillage. Each year, prior to tillage, those instruments near the soil surface were removed from the field, and the electrical leads and lysimeter tubes to the deeper instruments were coiled up, slipped into an inverted metal can, and buried below the depth of tillage and off to one side of the remaining instruments. After planting, a metal detector was used to locate the cans. The cans were then excavated, the leads and tubes were extended to the soil surface, and the shallow instruments were replaced in the tillage layer.

Ammonia traps, similar to those described by Volk (1959), were placed in the two urea plots and in one zero-N plot in each block immediately following fertilizer application each spring. Each trap was made from a 30- by 35-cm plastic dishpan 13 cm deep. Into the bottom of each pan, a pad of glass wool was placed, covered with 10-mesh plastic screen, and secured by four staples. 25 mL of ten percent sulfuric acid were dripped onto the pad. The traps were inverted directly over fertilized areas in the field. The traps were exchanged approximately every 24 hours until measurable precipitation ensured that urea hydrolysis was complete, or until ammonia volatilization could no longer be detected. As each trap was lifted from the soil, the lower rim of the dishpan was wiped with a paper towel to prevent soil from contaminating the pad as the pan was turned upright. The glass wool was removed from the pan, rolled up, and inserted into an 800-mL macro Kjeldahl flask. The pan was then rinsed three times with 50-mL aliquots of distilled water and the rinse water was also added to the flask. The flasks were stoppered and returned to the laboratory for nitrogen analysis.

Each spring, field activities were conducted in the following sequence: a) soil temperature measurements were begun soon after the snow left the field; b) as soon as the soil had thawed approximately 30 cm deep, tillage layer instruments were removed from the field and the leads and tubes from the deeper instruments were buried below the tillage layer; c) phosphorus and potassium fertilizers were uniformly broadcast over the study area at 30 and 45 kg/ha P and K, respectively; d) the study area was disked once with the disk being lifted over the ^{15}N microplots; e) new ^{15}N microplots were established in the urea-incorporated main plots and covered; f) urea and calcium nitrate fertilizers were broadcast over the appropriate 'incorporated' main plots; g) all main plots were disked again, lifting the disk over all ^{15}N microplots; h) the new ^{15}N microplots in the urea-incorporated main plots were uncovered and hand-fertilized; i) all ^{15}N microplots were tilled with a garden hoe; j) the entire area was seeded to barley; k) new ^{15}N microplots were established and covered in the urea-surface main plots; l) urea and calcium nitrate were broadcast over the appropriate 'surface' main plots; m) the new ^{15}N microplots in urea-surface main plots were uncovered and hand-fertilized; n) instrument leads were dug up and tillage-layer instruments were replaced in the soil.

Sample collection

Soil samples were collected from the main plots approximately every two weeks throughout the summer. The first sampling took place each spring prior to planting, and samplings were continued until after the soil surface had begun to freeze in autumn. A truck-mounted hydraulic soil probe was used, once a month, to collect the soil samples from the plots. It was driven down the alleys and backed into the plots to collect the samples. The use of the hydraulic sampler allowed undisturbed soil cores to be collected to the depth of thawing or until coarse sand or gravel was encountered. Two 3.8-cm diameter soil cores were collected from each plot on each sampling date. The cores were divided into depth increments of 0-15, 15-30, 30-60, 60-90, and 90-120 cm and the samples representing the same depth from the two cores were composited. The truck was somewhat destructive to the barley plants within the plots, however, so soil samples were collected with 1.9-cm diameter hand probes to a depth of 45 cm on alternate dates to reduce crop disturbance. On the dates of hand sampling, four cores per plot were collected and composited in 15-cm depth increments. Soil samples were placed on ice in an insulated box and returned to the laboratory where they were kept frozen until just prior to analysis for ammonium, nitrate, and urea.

Soil samples were collected from the ^{15}N microplots immediately after fertilizer application, approximately two weeks after application, and then once a month for the remainder of the growing season. All soil samples from ^{15}N microplots were collected with a 1.9-cm diameter hand soil probe. On each sampling date, two cores per microplot were collected to a depth of 45 cm. These samples were divided into 15-cm increments and composited with depth. To reduce contamination, the soil probe was cleaned between plots by pushing it into the soil two or three times outside of the plot area. Soil samples from the ^{15}N microplots were also transported on ice to the laboratory and kept frozen until time of analysis.

Plant tissue samples were collected from each main plot three times during each growing season. The first sampling was conducted when the barley plants were approximately 15 cm high, the second sampling was when the crop was beginning to head (boot stage), and the third sampling was when the barley had reached physiological maturity. Plant samples consisted of total above-ground barley plants, hand-clipped with pruning shears, from two random areas 17 by 30 cm (30 cm of 1 row) within each plot. These samples were composited for each plot for determination of plant production and plant N uptake per unit area. Plant samples were transported on ice to the laboratory and immediately placed in a dryer at 60°C. They were then weighed, ground in a Wiley Mill to pass a 1-mm screen, and stored for whole plant (minus roots) analysis.

Plant samples were collected from the ^{15}N microplots only once each year, at physiological maturity. Considering the size of the microplots, sampling earlier in the season would have had a significant effect on nutrient uptake and on the soil environment. Total above-ground plant samples were hand-clipped from an area 68 by 70 cm (70 cm of 4 rows) in each plot. The ^{15}N plant samples were prepared for analysis the same as other plant samples except that special care was taken in cleaning the Wiley Mill with a brush and vacuum cleaner between samples to prevent ^{15}N contamination from one sample to another.

Grain yields were determined from each of the main plots by harvesting a strip 122 cm wide by 800 cm long from the middle of each plot with a plot combine. Grain samples were collected in bags, dried in a drying shed with circulating air at approximately 30°C, cleaned with a seed cleaner, and weighed. A subsample was oven dried to determine moisture content, and all weights were corrected to 12.5% moisture.

Soil water samples were collected from the ceramic cup lysimeters approximately every two weeks from the time the samplers thawed in spring until they froze in autumn. On each sampling date, a vacuum was drawn on the lysimeters and allowed to sit for a minimum of six hours. Soil water samples were collected in 133-mL polypropylene specimen containers and kept cool until they were returned to the laboratory where they were frozen until just prior to analysis.

Soil temperatures from the buried thermisters and soil moisture tensions from the gypsum blocks were recorded approximately every two weeks from the time that snow left the field in spring until snow covered the ground the following autumn. Soil moisture tension was determined from a standard curve which correlated voltage readings with known levels of soil moisture tension.

Laboratory Procedures

Ammonia volatilization samples

Within a few days following sample collection, the macro-Kjeldahl flasks containing glass wool and sulfuric acid from the ammonia traps were opened and 200 mL distilled water, 10 mL 10*N* sodium hydroxide, and three pieces of mossy zinc were added. The flasks were immediately connected to a macro-Kjeldahl distillation unit. Each sample was distilled until approximately 150 mL of distillate was collected in an Erlenmeyer flask containing 50 mL of a mixture of two percent boric acid solution and bromocresol green-methyl red indicator (Bremner, 1965). The distillate was titrated with 0.01*N* H_2SO_4 to determine the amount of ammonia-N captured in the sample.

Soil samples from main plots

Soil samples were prepared for analysis by crushing the soil to pass through a 2-mm sieve and thoroughly mixing to assure a representative sample. A 10-gram (field moist) subsample was extracted with 100 mL 2*N* KCl. The soil and KCl were shaken for one hour, filtered, then duplicate aliquots of the extract were analyzed on a dual channel Technicon II Autoanalyzer for ammonium N and nitrate N by methods described by Technicon (Whitledge *et al.*, 1981). Soil extracts were spot checked throughout the study for nitrite, but concentrations were always found to be less than 0.1 µg/g. Thus, NO_3^--N and NO_2^--N were always reported together as NO_3^--N. A separate subsample of soil was oven dried at 105°C to determine moisture content. All results were then converted to an oven-dry basis.

Soil samples collected from urea plots during the first two weeks after fertilizer application were analyzed for urea content as a check on the rate of urea hydrolysis. In this procedure, a 10-g sample of soil was extracted with 100 mL 2*N* KCl to which a urease inhibitor, phenylmercuric acetate (PMA), had been added. The sample was shaken for one hour and filtered. The filtrate was then analyzed colorimetrically for urea by a modified diacetyl monoxime method (Mulvaney and Bremner, 1979). Maximum absorbance at 527 nm was read on the spectrophotometer and compared to an absorbance curve of known standards.

Soil samples from ^{15}N microplots

Ammonium and nitrate concentrations in soil samples from ^{15}N microplots were determined by analyzing 2*N* KCl extracts with the autoanalyzer by the same procedure as was used for the main plot soil samples. A 40-mL aliquot of each KCl extract was reserved for ^{15}N:^{14}N isotope ratio analysis. This aliquot was placed in a 250-mL Kjeldahl flask with approximately 0.2 g magnesium oxide and distilled for four minutes on a steam distillation apparatus (Bremner and Keeney, 1965). The ammonia distillate was collected in a 50-mL beaker containing 2 mL of 0.08*N* HCl. Approximately 0.2 g of finely ground Devarda alloy was then added to the Kjeldahl flask to reduce the nitrate to ammonium and the distillation process was repeated catching the ammonia distillate from the nitrate fraction in a separate beaker of HCl. The distillates containing the N from the ammonium and nitrate fractions were concentrated by evaporation in a hot water bath at 78°C. When the distillates were almost dry, they were transferred to 3-mL glass vials and returned to the water bath for desiccation to a dry NH_4Cl salt. The vials were tightly stoppered and shipped to Isotope Services, Inc., Los Alamos National Laboratory, Los Alamos, New Mexico where they were analyzed on an ^{15}N automated mass spectrometer. Extraction procedures were not duplicated. However, duplicate samples from each extract were analyzed on the mass spectrometer.

Total N content was determined for each sample from a separate 5 g sample of soil digested by a permanganate-reduced iron modification of the Kjeldahl method to include nitrate and nitrite (Bremner and Mulvaney, 1982). The digest was diluted to 500 mL with distilled water, and an aliquot was analyzed on the autoanalyzer to determine total N concentration. A separate 50-mL aliquot of the digest solution was distilled and desiccated for N-isotope ratio analysis by the same procedure as described for the ammonium and nitrate fractions.

Plant samples from main plots

Oven dry, ground plant material was well mixed and a subsample (approximately 100 mg) was digested in a 75-mL digestion tube with 5 mL of sulfuric acid and six micro selenized boiling granules. Samples were digested for 1.75 hours on a modified Technicon Bd-40 block digester in which the tubes rotated continuously in a carousel over heating elements to provide uniform heating at 380°C. All samples were analyzed in duplicate and each rack of 40 samples contained one blank and one standard (50 mg orchard leaves; National Bureau of Standards reference material No. 1571).

After digesting, the samples were allowed to cool, then diluted to 75-mL volume with distilled, de-ionized water. The samples were analyzed for nitrogen (organic N + NH_4^+ on channel 1, and NO_3^- on channel 2) on the autoanalyzer system described above.

Plant samples from ^{15}N microplots

Since the N-isotope ratio analysis required a minimum of 100 µg N in each sample, much larger plant samples had to be digested from the ^{15}N microplots as opposed to those from the main plots. Thus, the following macro Kjeldahl procedure was followed rather than the block digestion which was used for the main plot plant samples.

Oven dry, ground plant material was thoroughly mixed and a one gram subsample was digested by a salicylic acid-thiosulfate modification of the Kjeldahl method to include nitrate and nitrite (Bremner, 1965). Each sample was placed in a macro-Kjeldahl flask, 40 mL of sulfuric acid containing two grams salicylic acid were added (AOAC Methods, 1980), and the flask was swirled and allowed to stand overnight. Five grams of sodium thiosulfate were added, the flask was swirled, allowed to stand five minutes, then heated over a low flame until frothing had ceased. The flask was allowed to cool, then 20 mL distilled water and a 10-g packet of digestion salts ($CuSeO_3$ + K_2SO_4 + pumice) was added. The flask was returned to the heater until the solution cleared (20-40 minutes). The heat was then lowered until the mixture was just boiling, and heating was continued for approximately three hours. From this point on, the plant digests were handled the same way as the soil digests from ^{15}N microplots. The digests were diluted to 500 mL volume, an aliquot was run on the autoanalyzer for total N (as ammonia), and a 50-mL subsample of the digest was distilled for atom percent ^{15}N analysis.

Soil water samples

Soil water samples were thawed just prior to analysis. They were then analyzed for NH_4^+-N and NO_3^--N on the two channels of the autoanalyzer described above.

Statistical Procedures

All data were compared by analysis of variance (ANOVA) at the 0.05 level of probability. Means of treatments contributing significantly to the variability of the results were compared by the Waller-Duncan Bayes Least Significant Difference (BLSD) mean separation test (Petersen, 1985).

RESULTS AND DISCUSSION

Precipitation

May through September represents the general period during which the surface soil was thawed at the study site. Barley was planted during late May or early June each year and was harvested during mid August. September precipitation had no effect on the barley crop during the year which it was received but might have had an effect on leaching of residual N in the soil.

Precipitation records (Table 2) show that the growing season for 1982 was near normal through mid July, then very dry with little precipitation during the last two weeks of July and the month of August. Rainfall in 1983 was well below the 24-year average during June and the first week of July, but excessive rainfall during the remainder of July raised the total precipitation for the growing season to above the long-term average. In 1984, precipitation was nearer to the 24-year average with dry periods occurring only in early May and in September, before and after the peak periods of moisture demand for the barley crop.

Soil Moisture Tension

Initial analysis of soil moisture tensions showed a significant 3-way interaction of sampling date by fertilizer treatment by soil depth in two of the three years. Thus,

Table 2. Precipitation during the growing seasons at the study site.

Month	Week†	24-yr. avg (cm)	1982 (cm)	1983 (cm)	1984 (cm)
May	1		0.76	0.25	0.00
	2		0.00	0.13	0.00
	3		0.76	0.00	0.00
	4		0.25	1.85	1.50
	Total	**2.184**	**1.78**	**2.24**	**1.50**
June	1		0.00	0.00	0.51
	2		0.00	0.76	0.89
	3		6.86	0.81	4.50
	4		0.00	0.00	0.31
	Total	**5.740**	**6.86**	**1.58**	**6.20**
July	1		0.00	0.51	1.30
	2		3.56	2.41	5.49
	3		5.84	2.03	0.41
	4		0.51	5.84	2.31
	5		0.00	2.79	0.00
	Total	**6.807**	**9.91**	**13.59**	**9.50**
August	1		0.51	1.78	4.80
	2		0.25	0.51	0.20
	3		0.76	0.51	4.60
	4		0.25	0.76	0.00
	5		0.25	1.65	0.00
	Total	**5.080**	**2.03**	**5.21**	**9.60**
September	1		2.54	1.52	0.20
	2		2.54	0.25	0.00
	3		0.43	0.13	0.00
	4		0.08	2.79	0.10
	5		0.00	0.00	0.10
	Total	**3.150**	**5.59**	**4.70**	**0.41**
Seasonal	**Total**	**22.961**	**26.170**	**27.320**	**27.21**

† Total precipitation for the preceding week was recorded each Monday.

separate ANOVAs were conducted comparing the effects of fertilizer treatments and sampling dates on soil moisture tension at each soil depth in each year (Table 7, Appendix). Soil moisture tension means for fertilizer treatments were compared by BLSD where significant differences were shown by the ANOVAs (Table 8, Appendix).

Fertilizer treatments had little effect on soil moisture tension except during dry periods starting in late July in both 1982 and 1983. During those dry periods, soil moisture tension was considerably higher in the N-fertilized plots than in those plots receiving no N. This indicates that considerably more water was used by barley which had received N fertilizer as compared to that which had not. Although differences in soil moisture among N-fertilized plots were sporadically significant, the magnitude of these differences was not great. Hence, for each of the three growing seasons, moisture tension means for all N-fertilized plots were combined and compared to soil moisture tension means for those plots receiving zero-N (Figures 2, 3, and 4).

Soil moisture held at low tension is readily available for plant use. As soil moisture tension increases, soil water becomes less available to plants. Moisture held at tensions greater than 1500 kPa is usually considered to be held too tightly to supply the needs of agricultural crops (Richards and Weaver, 1943). It is evident from Figures 2, 3 and 4 that barley plants that had received N fertilizer probably suffered from moisture stress for short periods in both 1982 and 1983, but not in 1984.

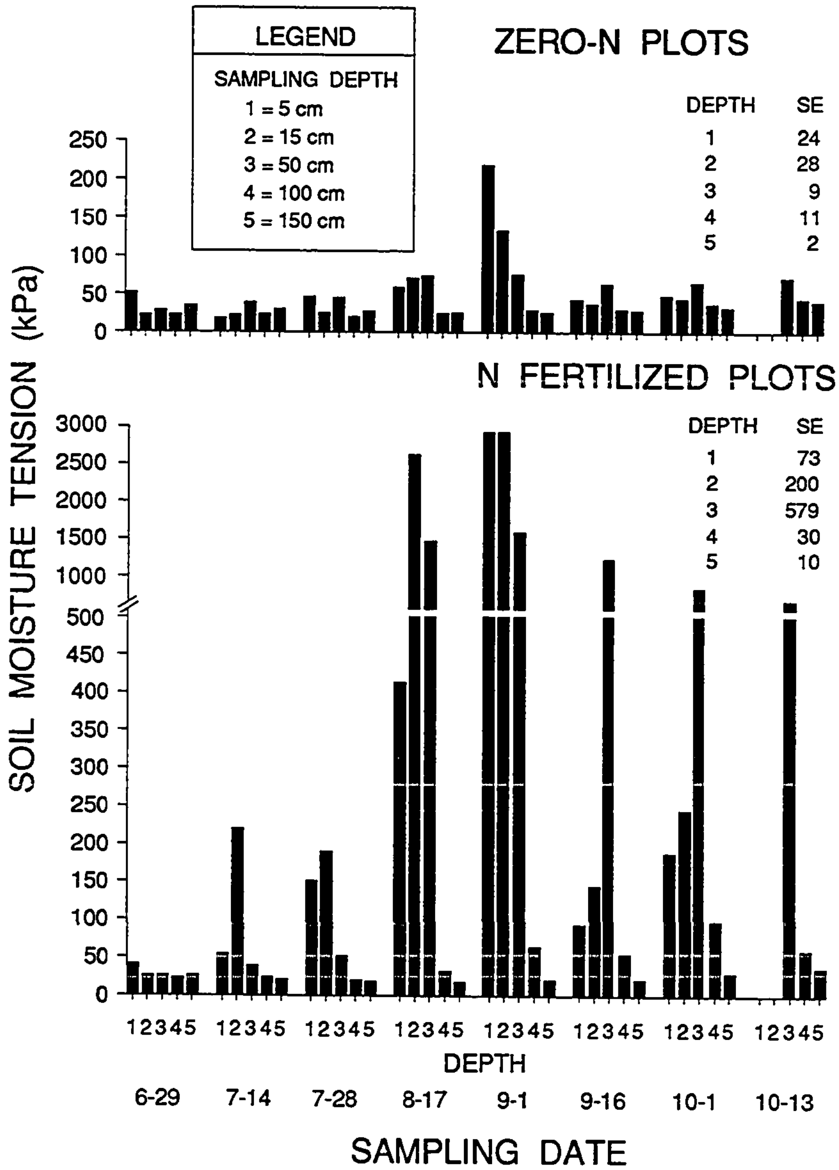

Figure 2. 1982 average soil moisture tension in barley plots with and without nitrogen fertilization. SE = a typical standard error.

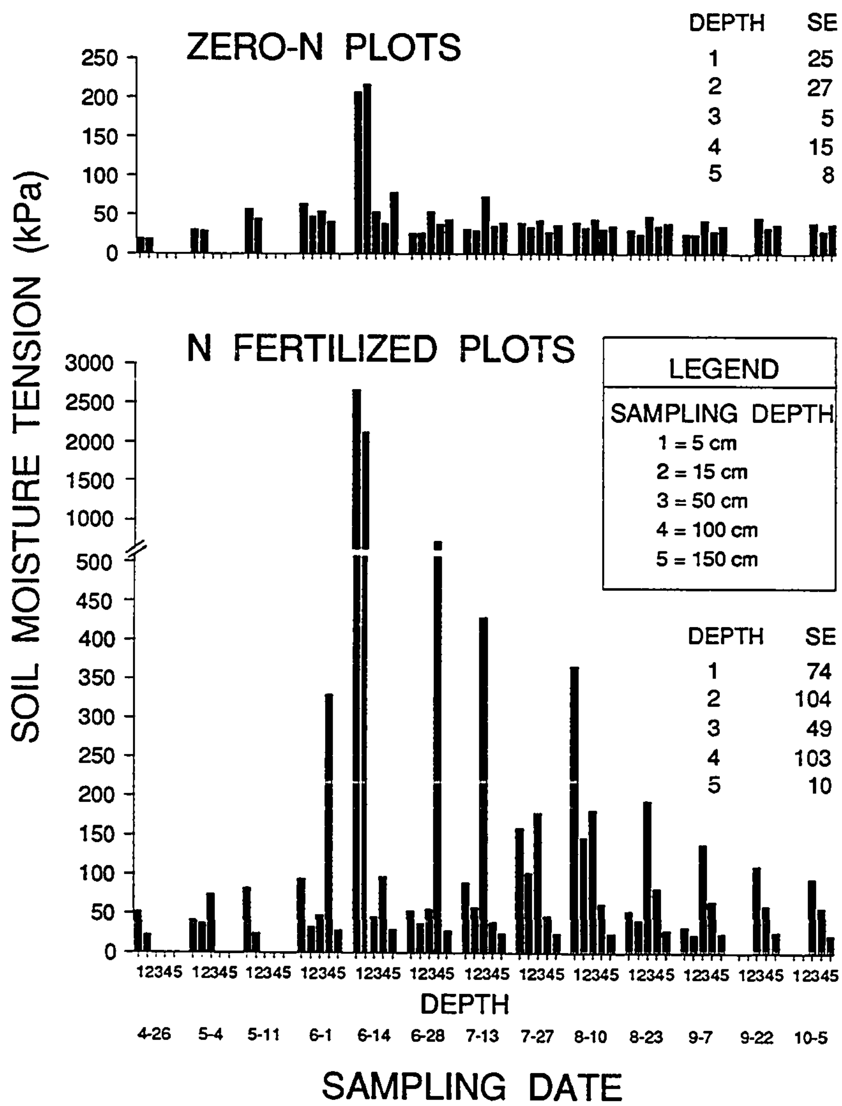

Figure 3. 1983 average soil moisture tension in barley plots with and without nitrogen fertilization. SE = a typical standard error.

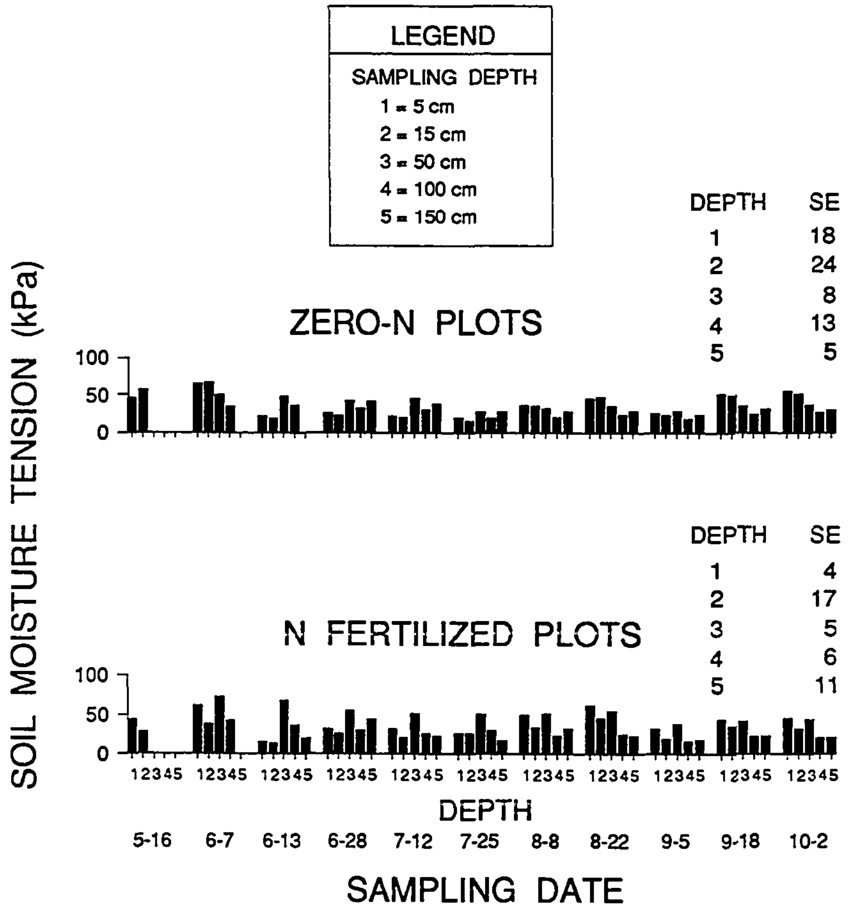

Figure 4. 1984 average soil moisture tension in barley plots with and without nitrogen fertilization. SE = a typical standard error.

In 1982, the crop was physiologically mature on August 17 and high moisture tensions were first measured on that date. Thus, the plants were probably stressed for moisture for a portion of the two weeks prior to physiological maturity. The soil moisture tension at the 5-cm depth was only 450 kPa on the day it was measured. However, higher moisture tensions at the 15- and 50-cm depths (2500 and 1500 kPa, respectively) indicate that drier conditions must have occurred at the 5-cm depth on an earlier date as it is not likely that soil water would have been removed to so great a tension at the 15- and 50-cm depths if water had been more readily available at the 5-cm depth. Although the water holding capacity of the soil was not measured in this study, it is interesting to note that 5.08 cm of precipitation in early September significantly reduced soil moisture tensions at the 5- and 15-cm depths but had very little effect at the 50-cm depth.

In 1983, precipitation was well below average for the month of June and soil moisture tension was notably high in the top 15 cm of the soil profile on the June 14 sampling date. Although rains soon reduced soil moisture tensions at the 5- and 15-cm depths, the soil remained relatively dry at greater depths throughout most of the summer. In 1984, precipitation was received on a regular basis, and soil moisture tension was never measured above 63 kPa.

Soil Temperature

Statistical analysis of soil temperatures showed significant two-way interactions of sampling date by fertilizer treatment and sampling date by soil depth, and sometimes, significant three-way interactions of sampling date by fertilizer treatment by soil depth. Thus, separate ANOVAs comparing the effects of fertilizer treatments and sampling dates on soil temperatures were conducted for each soil depth in each year (Table 9, Appendix). Mean separations of soil temperatures are shown in Table 10 (Appendix).

Soil temperature differences among fertilizer treatments were greatest at the shallow (5-cm) soil depth. At that depth, soil temperatures in plots which had received no fertilizer N were generally slightly warmer than in those which had received fertilizer N. This was apparently due to less plant growth in the zero-N plots resulting in less crop shading during the growing season and less straw accumulation to delay the soil from warming in the spring. Although temperatures at the 5-cm depth were highest in the zero-N plots on 85 percent of the sampling dates, those differences were usually not greater than one or two degrees and were significantly ($P \leq 0.05$) greater than in the N-fertilized treatments on only 18 percent of the sampling dates. Hence, the soil temperatures for all fertilizer

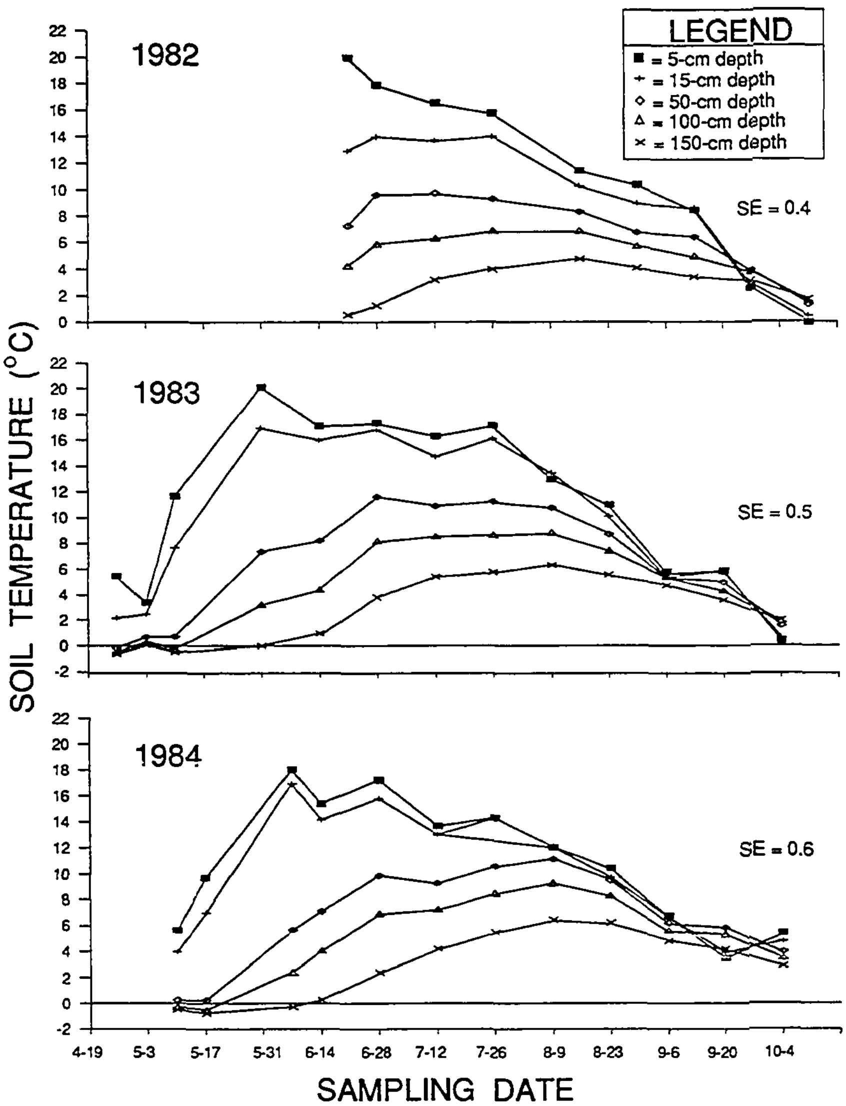

Figure 5. Soil temperature profiles for the three growing seasons. SE = a typical standard error.

treatments were averaged together to show soil temperature profiles for the three years of the study (Figure 5). Shortly after planting, around the first of June, soil temperatures at the 5- and 15-cm depths reached a maximum of approximately 20°C and 17°C, respectively. Surface soil temperatures slowly diminished for the remainder of the growing season, probably due to shading from the crop canopy. Soil temperatures at or below the 50-cm depth remained cool throughout the season, rarely reaching 10°C.

Ammonia Volatilization

Each year, urea granules dissolved and disappeared from the soil surface within a few hours following fertilizer application. The quantities of ammonia N captured in the volatilization traps were very small on each sampling set, amounting to only a few grams of NH_3-N per hectare per day. Each year, only the first two sets of ammonia volatilization samples, captured over a period of approximately 24 hours each, contained measurable amounts of N. Initial statistical analysis indicated a significant interaction between year and sampling set, so the results from each year were analyzed separately (Table 11, Appendix). Mean volatilization losses for each fertilizer treatment and for each sampling set are shown in Table 12 (Appendix).

Although, each year, surface-applied urea showed slightly higher ammonia volatilization than either incorporated urea or zero-N treatments, losses were so small and variable that they were statistically significant only in 1984. Even in that year, ammonia losses each day from plots receiving surface-applied urea exceeded ammonia losses from plots receiving zero-N by only 0.008% of the applied urea N. Considering the short time between urea application and urea hydrolysis, such losses were considered negligible. In 1983, significantly more ammonia was captured in the first few hours after application than was captured in the second 24-hour period. However, volatilization was, again, so low that it was considered negligible.

Urea Hydrolysis

The bulk density of dry soil in the 0-15 cm layer at the study site averaged 1.05 g/cm^3. Thus, the fertilizer N application rate of 100 kg N/ha was equivalent to approximately 62.3 µg N/g of dry soil in the top 15 cm of the soil profile. To determine the initial urea recovery rate one might expect from a field sample, eight 1.9-cm diameter soil samples were collected and composited, in 1982, from the top 15 cm in each main plot within two hours following fertilizer application. The samples were placed in a freezer within an hour of collection and stored approximately six months, then thawed just prior to analysis. Urea concentrations in the samples were highly variable showing a mean urea N concentration of 23.1 µg N/g dry soil with values ranging from 1.5 to 107.7 µg N/g. The high variability between samples was obviously a result of the urea fertilizer being applied in a coarse, granular form. Although each soil sample consisted of a composite of eight soil cores, urea concentrations varied greatly depending on the number of urea granules collected with each soil core. Variability was greatest on plots where urea had been surface applied because the rounded granules tended to roll off of clods and concentrate in depressions in the soil surface, thus, making it difficult to collect representative soil samples. Also, the tilled layer of soil was loose and fluffy due to sampling the same day that the plots had been tilled and planted. Hence, one had to be extremely careful that loose soil and fertilizer granules did not fall out of the slot in the soil probe during the sampling operation.

Although urea was applied at a rate of 100 kg N/ha, the low mean urea N recovery rate of 23.1 µg N/g dry soil (37 kg N/ha) suggests that urea was rapidly hydrolyzing in the soil in the short time prior to the sample freezing. Relatively high ammonium concentrations in the samples confirmed these observations. Urea hydrolysis may also have occurred during the thawing period in the laboratory and during the processes of screening and weighing, prior to extraction with the KCl-PMA solution.

Due to the difficulties in collecting a representative sample immediately after fertilizer application, and since the objective of this study was not to determine the exact rate of urea hydrolysis in the first few hours after application but rather to determine if urea hydrolyzed rapidly enough in the soil to be available for plant uptake when it was needed, the decision was made to collect soil samples approximately two weeks after fertilizer application and analyze them to determine if residual concentrations of urea could be detected at that time. Only a few of those samples were found to contain traces of urea during the three years of the study. Since two weeks after fertilizer application corresponded closely with total crop emergence, the rate of urea hydrolysis was not considered to be a limiting factor in affecting fertilizer N availability to the barley crop.

Soil Water Samples From Lysimeters

The collection of soil water samples was somewhat sporadic even though vacuums were placed on the ceramic cup lysimeters approximately every two weeks each summer. Several of the lysimeters were plagued with slow vacuum leaks. Many lysimeters, especially those placed at the

150-cm depth, remained frozen until well into the growing season. Also, the soil texture varied from silt-loam to sand at the deeper sampling depths throughout the study. This meant that samplers at the same depth might be surrounded by soils with considerably different hydraulic conductivities. Although soil moisture tension was relatively uniform at a given depth, a coarse-textured soil holds less water than a fine-textured soil at a given soil moisture tension and, during dry periods, might not release water rapidly enough for a sufficient sample to be collected during the sampling period. Thus, if no water was collected from a sampler on a given date, it was difficult to determine if it was the result of a vacuum leak, a frozen lysimeter, soil moisture tension greater than the air entry value of the ceramic cup, or a combination of high soil moisture tension and coarse textured soil causing a soil water flow that was too slow for a sufficient sample to be collected during the sampling period. Although a complete loss of vacuum was usually indicative of some type of vacuum leak, samplers could only be excavated and repaired in early spring or late autumn without causing considerable crop disturbance, and during those times, frozen soil hindered digging. Hence, the average success rate for collection of soil water samples was slightly less than 30 percent.

Measurable amounts of ammonium N were not found in any of the soil water samples, so only nitrate N was recorded. Since sampling dates were not consistent among years, and differences in nitrate-N concentrations at the different sampling depths were not consistent among sampling dates within each year, separate ANOVAs were run for each sampling depth each year (Table 13, Appendix). These ANOVAs showed that nitrate concentration in the soil water was always significantly affected by fertilizer treatment, sampling date, or an interaction between the two. Hence, mean nitrate-N concentrations in soil water samples were compared by BLSD (Table 14, Appendix) and plotted in Figures 6, 7, and 8. Standard errors were calculated for each fertilizer treatment on each sampling date. However, despite the large amount of missing data, individual standard errors did not differ greatly. Thus, an average standard error was reported for each graph.

In 1982, the highest nitrate concentrations in soil water at the 75-cm depth were found on June 29 (Figure 6). This sampling came immediately after a week during which 6.86 cm of rainfall had been received following an unseasonably dry spring. Nitrate-N concentrations in the soil water at that depth were 25.1, 10.6, and 5.9 µg/mL from the plots receiving calcium nitrate, urea, and zero-N, respectively, indicating some downward movement of

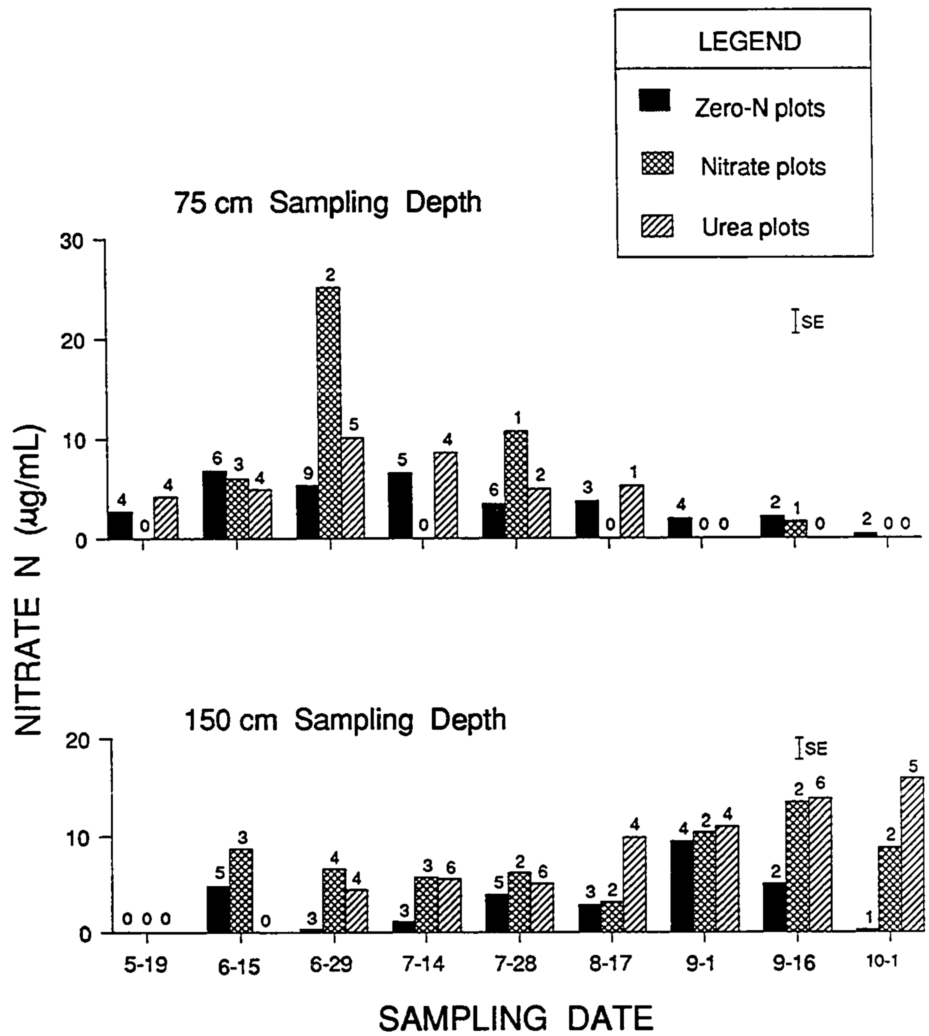

Figure 6. Nitrate-N concentration in 1982 soil water samples. Numbers above bars indicate the number of samples represented in that mean. SE = a typical standard error.

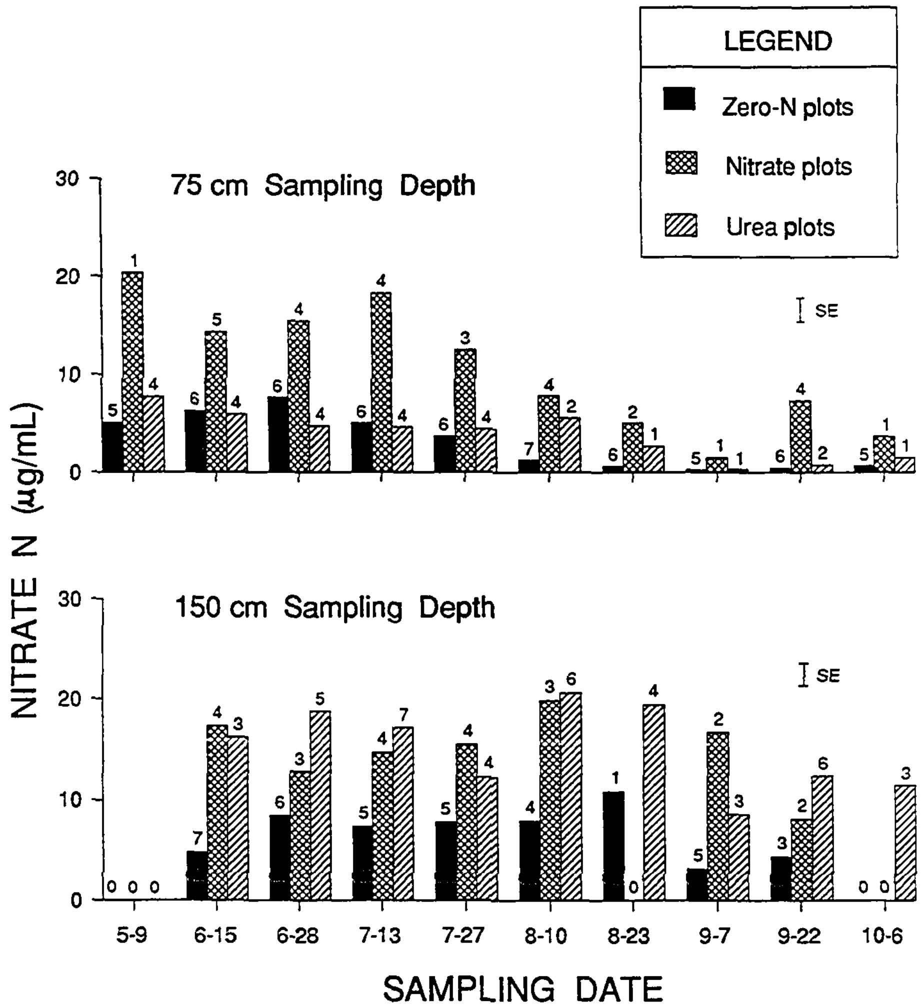

Figure 7. Nitrate-N concentration in 1983 soil water samples. Numbers above bars indicate the number of samples represented in that mean. SE = a typical standard error.

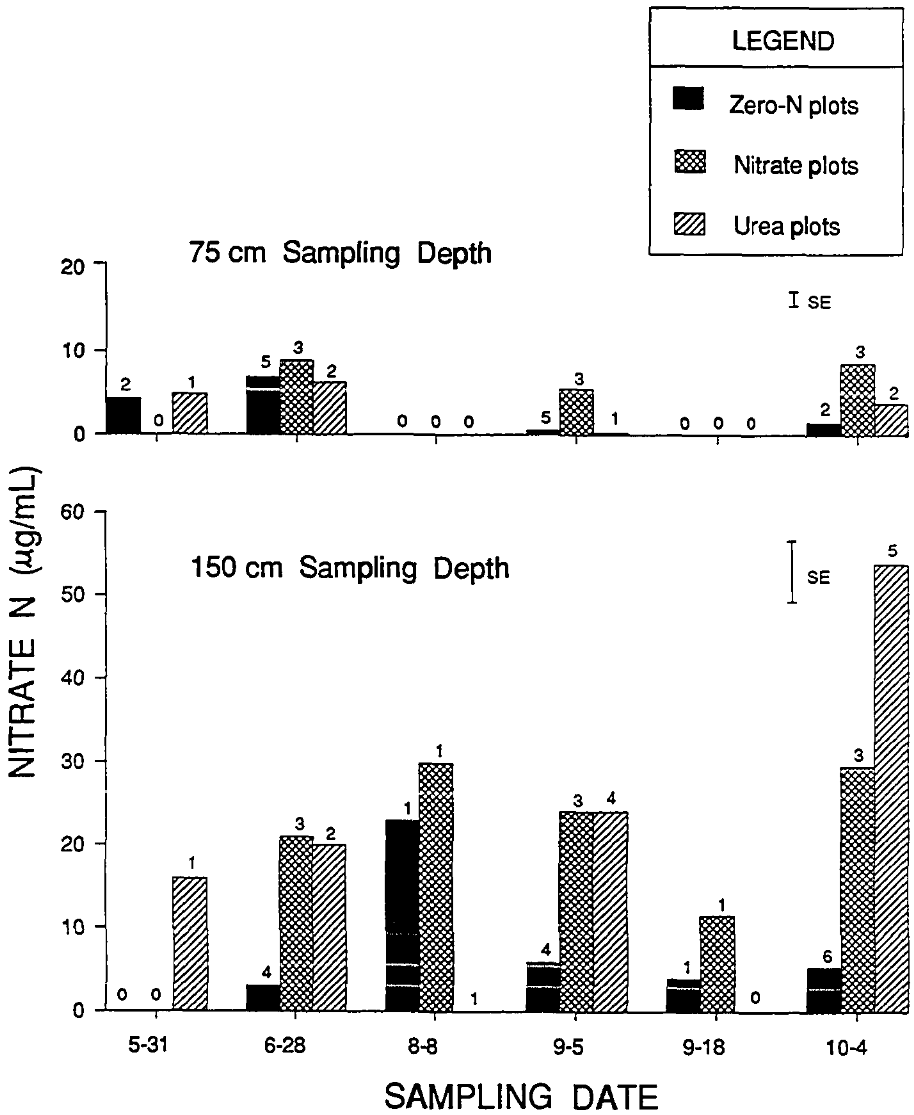

Figure 8. Nitrate-N concentration in 1984 soil water samples. Numbers above bars indicate the number of samples represented in that mean. SE = a typical standard error.

fertilizer nitrate on that date. However, there was no significant increase in nitrate at the 150-cm depth on that same sampling date. Nitrate concentrations at the 150-cm depth appeared to increase later in the season indicating the possible movement of nitrate deeper into the soil profile at some later date (Figure 6). However, during the latter part of the season the nitrate concentration at the 150-cm depth was not significantly greater than it had been on the June 15 sampling date (Table 14, Appendix). Also, soil moisture in the N-fertilized plots had always been measured at tensions greater than 500 kPa at some depth in the soil profile during the later part of the growing season (Figure 2), indicating little water movement through the soil profile. Thus, leaching of fertilizer nitrogen during the growing season to the 150-cm depth is doubtful.

In 1983, precipitation was near normal during May, low during June, and very high during July. Although nitrate concentrations at the 75-cm depth diminished during the growing season, there was no apparent correlation between precipitation and nitrate concentrations in the soil water. Mean nitrate concentrations in the soil water appeared considerably lower in zero-N plots than in N-fertilized plots, but the variability was so great among replications of the same treatment that the effect of fertilizer treatments on soil water nitrate was not statistically significant. Again, soil moisture tensions measured in the N-fertilized plots indicated a low probability of fertilizer leaching during the growing season.

During this three-year study, 1984 was the only growing season in which enough precipitation was received and soil moisture tensions were low enough to indicate the probability of saturated flow of soil water to the depth of 150 cm. By that year, several lysimeters at the 75-cm depth had become nonfunctional, but the few samples that were collected at that depth contained low concentrations of nitrate and showed no correlation with fertilizer treatments. Mean nitrate concentrations were slightly higher at the 150-cm depth than at the 75-cm depth throughout the season. At the 150-cm depth, the nitrate content of soil water in N-fertilized plots was significantly greater than in zero-N plots on one date, October 4, and significantly less than in the zero-N plots on one date, August 8. Since the last sampling date of the study, October 4, was the only date that the nitrate content of the soil water at the 150-cm depth in both the calcium nitrate and urea plots exceeded that of the zero-N plots, it is difficult to determine whether this sampling represents the chance interception of a flush of fertilizer nitrate leaching through the soil profile, or whether it might be explained as a normal fluctuation of soil water nitrate concentration similar to that which apparently occurred on August 8 causing a high nitrate concentration in the zero-N plots. Since nitrate leaching is a function of both, water movement and nitrate availability, this phenomenon will be further discussed later, after the results of the deep soil core analyses have been presented.

Plant Nitrogen in Main Plots

On each sampling date, fertilizer treatments were shown to have had a significant effect on N concentration in plant tissue, plant production (dry weight) per unit area, and N uptake by the plants (Table 15, Appendix). Hence, means of each of these data sets were compared by the BLSD mean separation test to determine which fertilizer treatments stimulated the greatest plant responses (Table 16, Appendix).

On all sampling dates, barley plants on plots which had received N fertilizer exhibited significantly higher N concentrations in the plant tissue, greater dry weight production, and higher N uptake per unit area than plants from zero-N plots. Also, plants which had been fertilized with calcium nitrate took up more N than plants that had been fertilized with urea. Although this greater plant uptake of N from the calcium nitrate source was not statistically significant ($P \le 0.05$) on all sampling dates, it was apparent on all dates except for the first sampling date of the first year of the study. On most sampling dates, the higher N uptake in calcium nitrate plots was a result of increases in both plant growth and N concentration in the plant tissue.

Many reasons have been reported for higher plant uptake of N from nitrate sources than from ammonium sources. Ammonium does not move through the soil with mass flow as nitrate does. Hence, plant roots must come into contact with ammonium to absorb it, whereas, nitrate may move into the root zone with soil water and may be taken up in greater quantities than ammonium, particularly early in the season when plants are small and their root systems are small. Other research has shown that soil microbes immobilize ammonium more readily than nitrate in the soil (Jansson, 1963). Thus, in soil where immobilization exceeds mineralization, most applied nitrate fertilizer is likely to end up in the plants, whereas, a larger portion of applied ammonium fertilizer is likely to end up in the soil organic matter. In soils containing expanding clays, ammonium ions may become trapped in the clay lattice and become temporarily fixed in a position unavailable for plant uptake. Much of this ammonium becomes fixed as the soil dries and the ammonium becomes sandwiched between clay lattices. Fixed ammonium may become available again for plant uptake or ion exchange when the soil becomes wet again and expands.

In this study, the Difference Method showed the greatest uptake of fertilizer N by plants during the driest season, 1983, and the lowest uptake of fertilizer N during the wettest season, 1984. Hence, ammonium fixation by drying clays does not appear to be a logical explanation for the greater uptake of nitrate N than urea N by plants. The difference was most likely due to greater mobility of nitrate in the soil and possibly to greater immobilization of ammonium from the urea source than nitrate from the calcium nitrate source.

There appeared to be a trend for slightly higher concentrations of N in plant tissue where N fertilizer had been applied on the soil surface as opposed to where it had been incorporated. This trend was consistent for both fertilizer materials on all sampling dates with the single exception of urea on 10 August 1983. Differences were small and were statistically significant on only a few sampling dates. Conversely, for 78 percent of the comparisons, plant dry matter production was slightly less where the fertilizer had been applied on the soil surface as opposed to where it had been incorporated. This dampening effect of greater plant growth and lower nitrogen concentrations in the plants from plots where the fertilizer had been incorporated, and vice versa where the fertilizer had been surface applied, resulted in no significant differences in N uptake per unit area by plants in either 1982 or 1984. In 1983, however, during the early growing season when precipitation was limiting, N uptake was significantly greater where the N fertilizer had been incorporated. Little precipitation was received during the first five weeks following crop emergence in 1983. During this dry period, barley emerged but made very little growth in plots where the fertilizer N had been applied on the soil surface, whereas, in plots where the N had been incorporated, barley continued to grow but showed visual signs of stress from insufficient N and/or moisture. In mid July, when adequate rainfall was finally received, the plants in surface-applied-N plots made a sudden growth spurt and rapidly surpassed the barley in incorporated-N plots in both height and head size. However, the delayed barley growth resulted in approximately two weeks delayed maturity in those plots (Sparrow *et al.*, 1984). Hence, barley in the incorporated-N plots matured before autumn frost and barley in the surface-applied-N plots was killed before it was fully mature resulting in light weight grain. Even during this dry season, the trend of increased plant growth and reduced N concentration in the plant tissue was apparent where the N fertilizer had been incorporated.

Available Soil Nitrogen in Main Plots

Statistical analysis of ammonium- and nitrate-N concentrations at each soil depth showed significant interactions for almost all combinations of: fertilizer treatments, sampling dates, and years. Thus, each date was analyzed separately to determine the effects of fertilizer treatments and soil depths on concentrations of ammonium and nitrate N in the soil (Table 17, Appendix). Treatment means are compared in Table 18 (Appendix), and the results are plotted in Figures 9-14.

Each year, the first soil sampling following (approximately two weeks after) fertilizer application showed that most inorganic soil N in the calcium nitrate and urea plots was in the nitrate and ammonium forms, respectively. Effects of fertilizer applications on soil inorganic N was statistically significant in only the upper 15 cm of the soil profile at the end of the first two weeks. High ammonium N concentrations in the urea plots indicated that the urea had hydrolyzed, but small increases in nitrate concentrations indicated that only a small portion of the fertilizer N had nitrified at that time. Nitrification proceeded fairly rapidly, however, and ammonium concentrations in the incorporated-urea plots had decreased to the point that they were no different from those in the calcium nitrate plots by six to seven weeks following

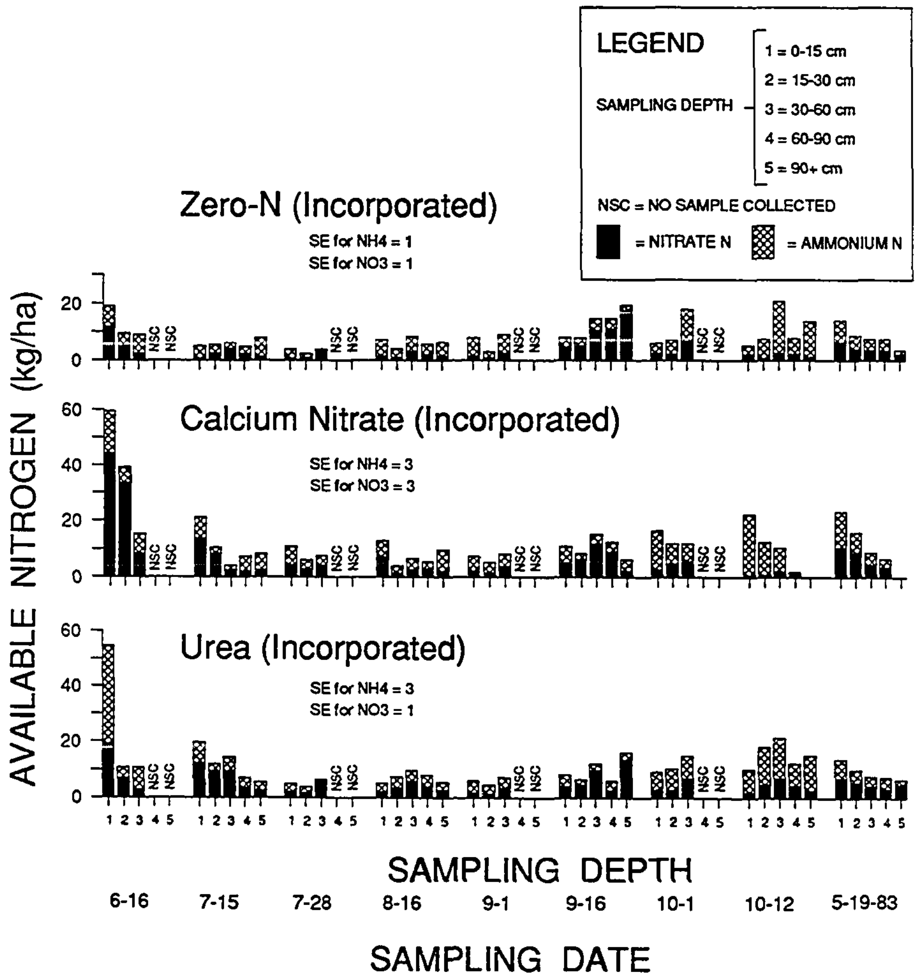

Figure 9. Available nitrogen in the soil profile of incorporated-fertilizer plots during the 1982 growing season. SE = a typical standard error.

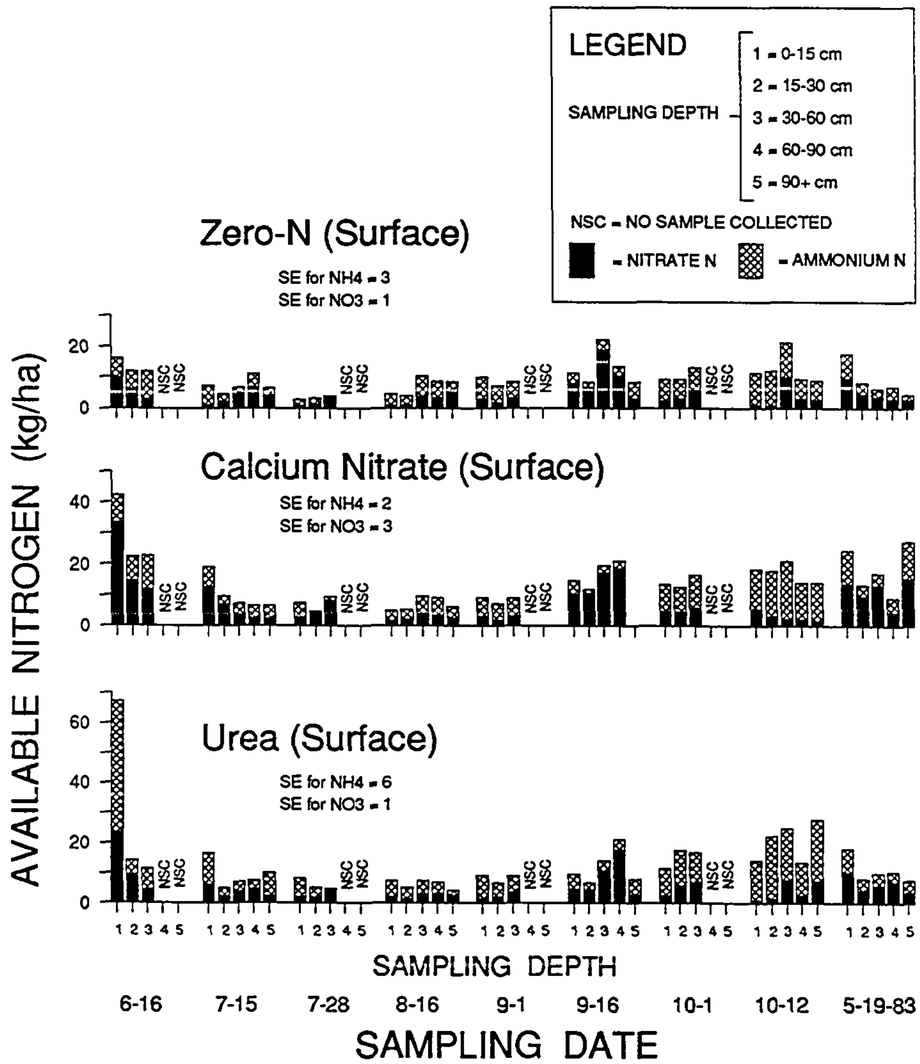

Figure 10. Available nitrogen in the soil profile of surface-fertilized plots during the 1982 growing season. SE = a typical standard error.

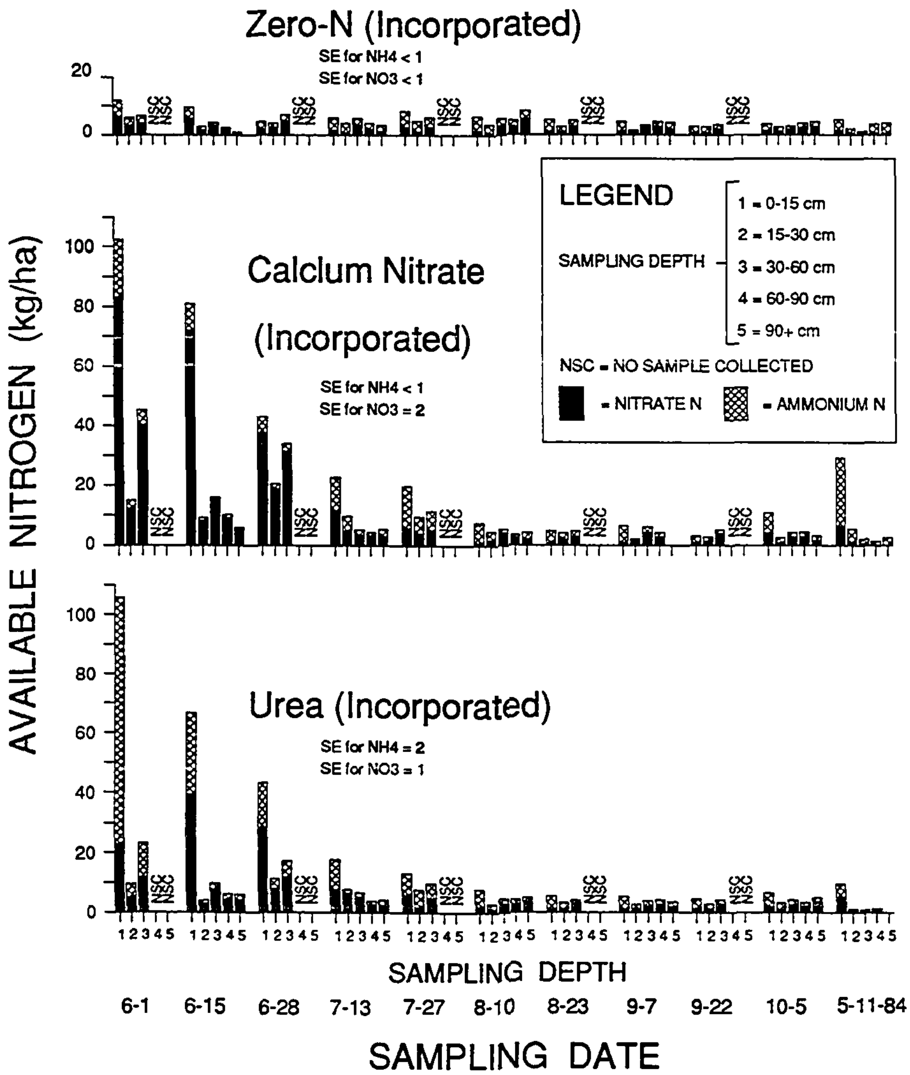

Figure 11. Available nitrogen in the soil profile of incorporated-fertilizer plots during the 1983 growing season. SE = a typical standard error.

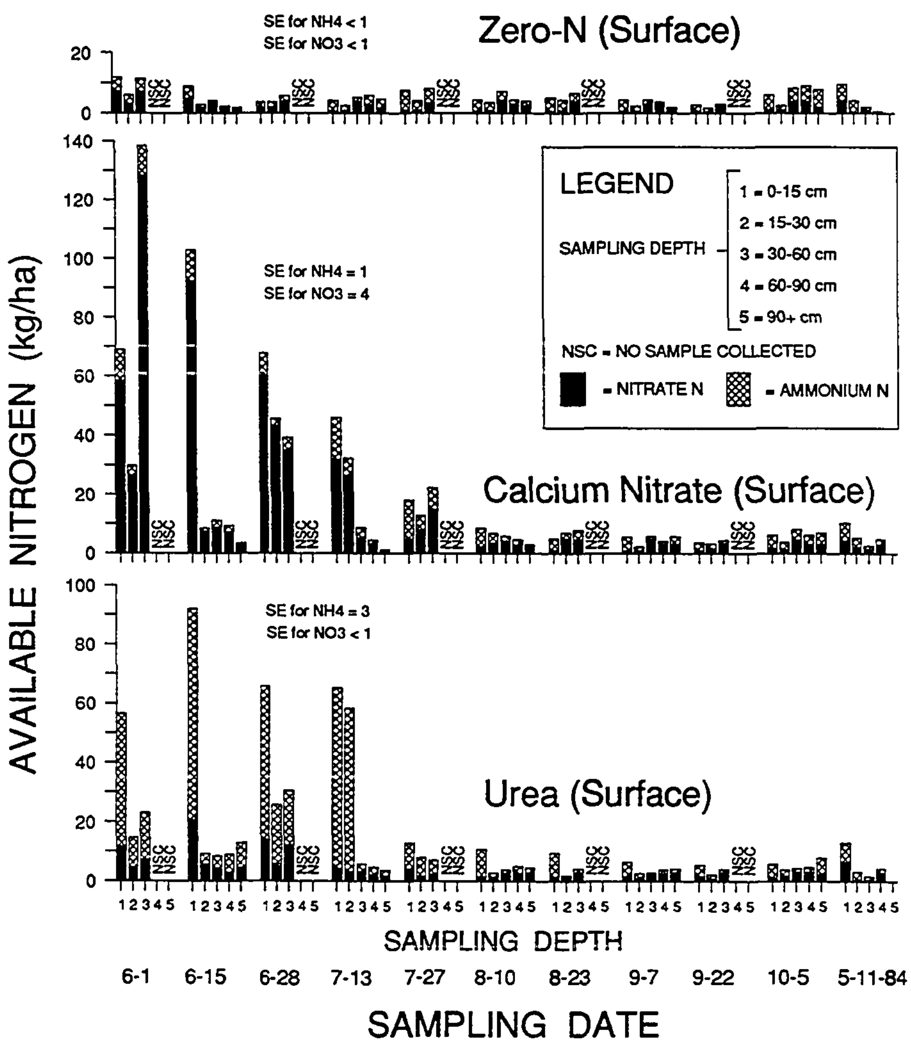

Figure 12. Available nitrogen in the soil profile of surface-fertilized plots during the 1983 growing season. SE = a typical standard error.

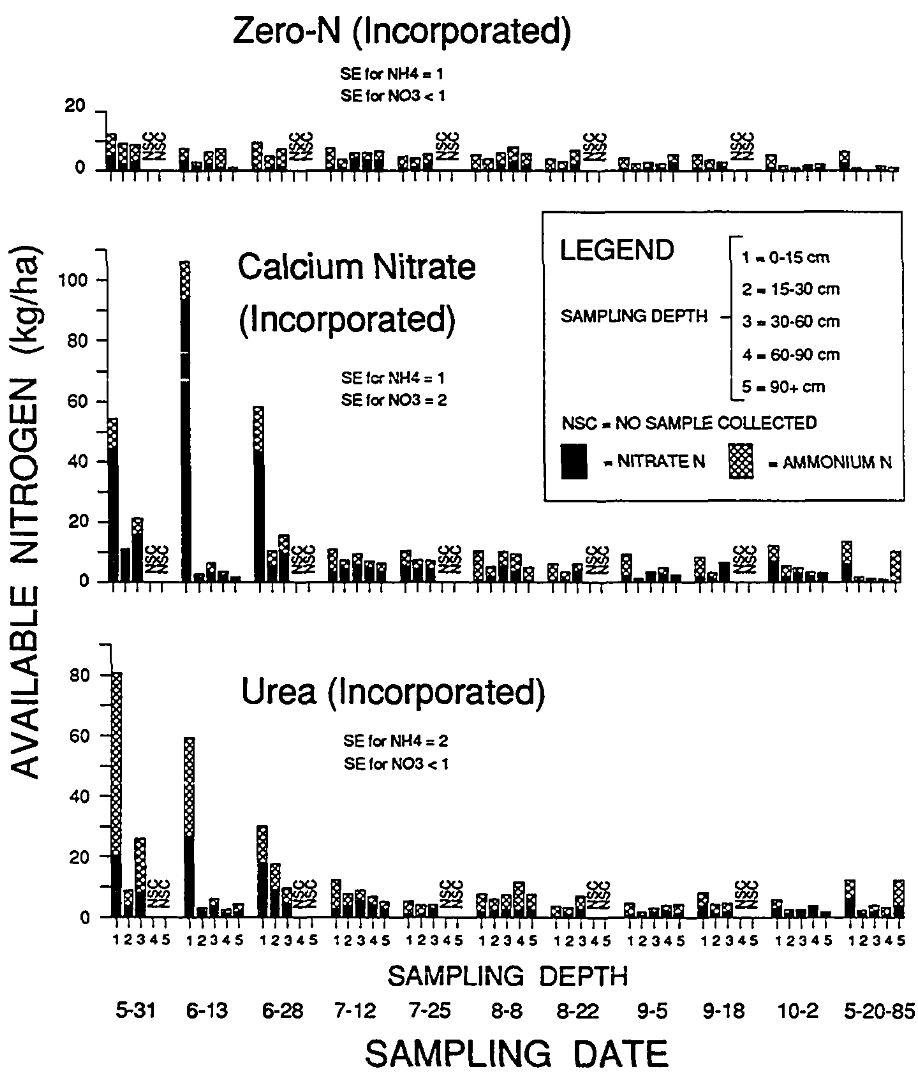

Figure 13. Available nitrogen in the soil profile of incorporated-fertilizer plots during the 1984 growing season. SE = a typical standard error.

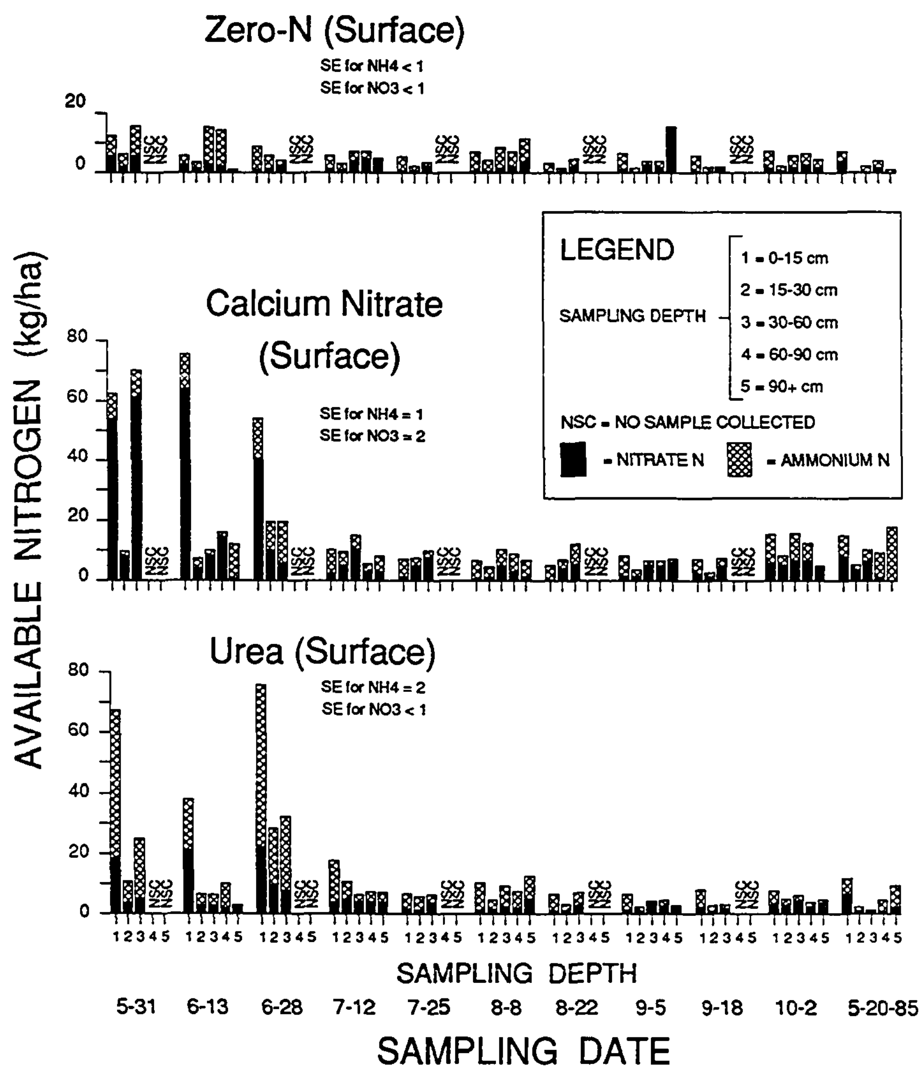

Figure 14. Available nitrogen in the soil profile of surface-fertilized plots during the 1984 growing season. SE = a typical standard error.

fertilizer application. Ammonium disappearance as a result of nitrification and/or plant uptake was sometimes slower where the urea had been applied on the soil surface as opposed to where it had been incorporated, and in 1983 and 1984, ammonium concentrations in plots where urea had been surface applied were significantly higher than in the calcium nitrate plots for 9 to 10 weeks following fertilizer application.

Net seasonal mineralization of soil N was estimated by the amount of N taken up by the crop on zero-N plots. Baseline soil samples (Table 1) showed that there was approximately 24 kg N/ha available in the top 30 cm of soil at the beginning of the study. At the end of the first growing season, plants on the zero-N plots had taken up an average of 35 kg N/ha. Hence, an estimate of the net seasonal N mineralization in the soil during that first season would be the difference of these two values or 11 kg N/ha. During the following two years, crops on zero-N plots took up approximately 13 and 15 kg N/ha. Thus, during the three years of this study, the unfertilized soil averaged a net seasonal N mineralization rate of 13 kg N/ha (Table 16, Appendix).

Nitrate leaching was apparent by increases in the soil NO_3^--N concentration to a depth of 30-60 cm each year following fertilizer application, and by the noted increase in nitrate content of soil water at the 75-cm depth in N-fertilized plots following heavy rains in 1982. There was no indication, however, whether nitrate at that depth continued to leach downward with successive rains, or whether it moved back upward at a later date. Braley (1980), studying water movement in an agricultural soil near this study site, showed that the net water movement was upward in the soil profile during the growing season. Soil moisture tension records (Figures 2-4) indicate there was little water movement down to the 150 cm soil depth during the growing seasons of 1982 or 1983, but that such movement was likely in 1984. Although soil water nitrate concentrations at the 150-cm depth were positively correlated with N-fertilizer applications on only the last sampling date of the study, a gradual increase in soil water nitrate was apparent at that depth and mean concentrations of 8.1, 15.8, and 25.4 µg NO_3^--N/mL were detected in N-fertilized plots in 1982, 1983, and 1984, respectively. Compared to the mean concentrations in zero-N plots of 3.8, 7.1, and 6.9 µg NO_3^--N/mL at that depth, it appears that N-fertilization must have had a positive effect on nitrate leaching even if significant differences could not be detected in soil and water samples on individual sampling dates.

Much of the nitrate at the deeper sampling depths may not have come directly from fertilizers but from increased mineralization and nitrification in the N-fertilized plots during autumn or spring when no crop was growing on the plots. Figures 9 and 10 show a considerable increase in soil nitrate in the autumn of 1982 and spring of 1983. Allison (1973) reported that leaching is least likely to occur in the summer when evapotranspiration is high. Thus, significant leaching in an interior Alaska agricultural soil would logically occur either during heavy rains arriving in the first few weeks following fertilizer application or in the autumn or spring when the soil is thawed, evaporation is low, and there is no crop uptake. Although there are indications that some nitrate leaching occurred in this study, leaching losses can only be grouped with denitrification losses and estimated from the quantities of fertilizer N that could not be recovered in the various N pools that were sampled when the barley was physiologically mature each year.

Fertilizer Nitrogen Budgets in Main Plots.

Since plant tissue samples were collected, each year, at three approximate growth stages (15-cm height, boot stage, and physiological maturity), and soil samples were collected on those same dates, it is possible to calculate fertilizer N budgets for main-plot treatments on each date by comparing N-fertilized to zero-N plots using the Difference Method (Hauck and Bremner, 1976). Quantities of N per hectare in the forms of ammonium, nitrate, and plant N were calculated for each fertilizer treatment on each sampling date. Since there was no apparent difference between the two zero-N treatments in each block, N values from the zero-N treatments were averaged together to obtain control values which were then subtracted from the corresponding N values obtained from each N-fertilized plot in that same block. Means of the differences between N fertilized and zero-N treatments (Table 3) provide an indication of fertilizer N distribution on each sampling date. It is recognized that this approach does not account for fertilizer N that had been immobilized by soil microbes; it does not provide any indication of N losses from the system by leaching, volatilization, etc.; nor does it prove that the detected N came from the fertilizer source. However, it does give a good indication of the plant and soil response associated with the applied N fertilizer and serves as a good comparison for fertilizer N budgets determined by the Isotope Dilution Method in the ^{15}N microplots.

Since fertilizer N was applied at a rate of 100 kg/ha and the corresponding N values from control plots have been subtracted, the values in Table 3 may be viewed as a

Table 3. Total plant N and available soil N in N-fertilized plots in excess of that in zero-N plots.

Sampling Date (days after fert. appl'n)	Fertilizer Treatment	NH_4^+-N 0-45 cm (kg/ha)	NO_3^--N 0-45 cm (kg/ha)	Total Plant-N (kg/ha)	Detected† Fert. N (kg/ha)
14 JUL 82 (41)	Nitrate (Inc)	6.7	35.6	29.2	71.5
	Nitrate (Surf)	4.4	21.9	36.7	63.0
	Urea (Inc)	18.7	8.5	38.1	65.3
	Urea (Surf)	23.4	9.3	36.2	68.9
28 JUL 82 (55)	Nitrate (Inc)	1.4	11.3	61.8	74.5
	Nitrate (Surf)	1.1	7.8	64.5	73.4
	Urea (Inc)	2.7	12.2	41.6	56.5
	Urea (Surf)	2.8	3.7	42.8	49.3
17 AUG 82 (75)	Nitrate (Inc)	3.7	3.5	57.5	64.7
	Nitrate (Surf)	1.3	3.0	79.0	83.3
	Urea (Inc)	0.8	1.8	69.0	71.6
	Urea (Surf)	2.8	1.6	55.9	60.3
13 JUL 83 (54)	Nitrate (Inc)	2.5	36.0	63.5	102.0
	Nitrate (Surf)	3.3	61.7	46.6	111.6
	Urea (Inc)	9.5	21.2	59.0	89.7
	Urea (Surf)	42.6	11.1	37.4	91.1
27 JUL 83 (68)	Nitrate (Inc)	3.6	6.4	78.3	88.3
	Nitrate (Surf)	6.3	25.4	79.2	110.9
	Urea (Inc)	3.2	7.5	62.4	73.1
	Urea (Surf)	53.5	2.9	47.9	104.3
10 AUG 83 (82)	Nitrate (Inc)	4.8	3.9	79.2	87.9
	Nitrate (Surf)	6.6	9.5	79.6	95.7
	Urea (Inc)	2.4	2.0	71.4	75.8
	Urea (Surf)	2.7	1.4	57.8	61.9
28 JUN 84 (42)	Nitrate (Inc)	5.3	57.8	29.5	92.6
	Nitrate (Surf)	3.5	41.6	32.1	77.2
	Urea (Inc)	17.0	13.0	23.5	53.5
	Urea (Surf)	6.2	12.8	21.8	40.8
25 JUL 84 (69)	Nitrate (Inc)	2.9	3.0	46.8	52.7
	Nitrate (Surf)	3.7	3.5	45.4	52.6
	Urea (Inc)	3.9	3.3	36.4	43.6
	Urea (Surf)	7.6	3.4	46.2	57.2
08 AUG 84 (83)	Nitrate (Inc)	1.2	1.1	64.8	67.1
	Nitrate (Surf)	1.2	1.9	76.6	79.7
	Urea (Inc)	1.3	0.0	48.3	49.6
Means:	Urea (Surf)	1.1	0.2	59.0	60.3
Fertilizer	Nitrate (Inc)	3.6 a*	17.6 b	56.7 bc	77.9 b
	Nitrate (Surf)	3.5 a	19.5 b	60.0 c	83.0 b
	Urea (Inc)	6.6 a	7.7 a	50.0 ab	64.3 a
	Urea (Surf)	15.9 b	5.1 a	45.0 a	66.0 a
Growth Stage	15-cm stage	12.0 b	27.5 c	37.8 a	77.3 a
	Boot stage	7.7 ab	7.5 b	54.4 b	69.7 a
	Mature	2.5 a	2.5 a	66.5 c	71.5 a
Year	1982	5.8 a	10.0 a	51.0 ab	66.8 a
	1983	11.8 a	15.7 a	63.5 b	91.0 b
	1984	4.6 a	11.8 a	44.2 a	60.6 a

† Excess N in N fertilized plots as determined by Difference Method.
* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD).

percentage of the fertilizer N detected in the plants and in the soil available-N pools on each date. The average fertilizer N recovery rate for 1983 was significantly greater than for 1982 or 1984. This difference was due to slightly higher concentrations of ammonium and nitrate in the soil and significantly higher N uptake by the barley plants. During the dry spring of 1983, barley plants showed signs of severe stress from an insufficient supply of moisture and/or N, particularly in zero-N plots and in plots where N fertilizer had been placed on the soil surface. In those plots, very little barley growth took place until rainfall increased during the second week of July. Thus, the first plant sampling was delayed until a majority of the barley plants had reached 15 cm height, 54 days after fertilization in 1983 versus 41 and 42 days for 1982 and 1984, respectively. Barley plants produced vigorous growth during the few days prior to the first plant sampling and continued to grow rapidly through maturity. Initial stress followed by rapid growth may account for large quantities of N being taken up by plants during the 1983 season. The dry spring may also have reduced N leaching and immobilization in the soil prior to the time that the plants were ready to use it, thus, causing the noted increase in available forms of soil N.

By the Difference Method, three-year averages show that we can account for approximately 73 percent of the added N on each sampling date. Although there was some variation in the amounts of N detected in each of the N pools on various sampling dates, an increase in plant N was usually offset by a decrease in available soil N. Thus, fertilizer N detection rates remained fairly constant within each growing season.

By averaging the total plant N uptake at physiological maturity each year, one can estimate the N use efficiencies for each of the fertilizers. The three year average fertilizer N use efficiencies for calcium nitrate and urea were 73 percent and 60 percent, respectively.

Plant Nitrogen in ^{15}N Microplots

Plant samples were collected from the microplots at physiological maturity. Plant samples from plots fertilized with ^{15}N labeled urea, either incorporated or surface-applied, always exceeded plant samples from zero-N plots in: N concentration in the plant, atom percent ^{15}N in the plant, dry weight of plant material produced, and total plant N (Table 19, Appendix). Hence, the means of each of these plant measurements, as affected by fertilizer treatments, were compared by the BLSD mean separation test (Table 4).

Table 4. Mean separations of plant weight and nitrogen uptake from ^{15}N plots.

Fertilizer Treatment	1982	1983	1984
Plant Nitrogen Concentration (µg/g)			
Zero-N	5658.6 a*	7057.5 a	7898.6 a
Urea (Inc.)	11103.1 b	9156.4 b	10937.4 b
Urea (Surf.)	11581.0 b	9985.9 b	11038.5 b
BLSD	**2463.6**	**1755.2**	**1400.1**
Dry Weight of Plant Material (kg/ha)			
Zero-N	3744.8 a	1302.7 a	1466.7 a
Urea (Inc.)	8033.2 b	6119.0 b	5676.3 b
Urea (Surf.)	6861.9 b	6238.4 b	7533.9 c
BLSD	**1602.2**	**1381.1**	**1719.9**
Total N Uptake by Plants (kg/ha)			
Zero-N	21.2 a	9.2 a	11.5 a
Urea (Inc.)	88.9 c	55.4 b	62.1 b
Urea (Surf.)	77.7 b	63.1 b	82.8 b
BLSD	**10.0**	**16.3**	**24.6**
Atom % ^{15}N in Total Plant N			
Zero-N	0.385 a	0.412 a	0.380 a
Urea (Inc.)	3.024 c	3.033 b	2.967 b
Urea (Surf.)	2.743 b	2.957 b	3.028 b
BLSD	**0.190**	**0.274**	**0.213**
Fertilizer N Uptake by Plants (kg/ha)			
Zero-N	0.0 a	0.0 a	0.0 a
Urea (Inc.)	50.6 c	31.7 b	34.1 b
Urea (Surf.)	39.5 b	34.4 b	47.2 c
BLSD	**6.15**	**11.01**	**9.02**

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Plant response to the position of urea fertilizer placement was similar in ^{15}N microplots to that in the main plots in 1982 and 1984, but differed in 1983. In 1982, greater plant growth and diluted N concentration in plant tissue, from plots where the urea had been incorporated, was also noted in the microplots. However, in the microplots, incorporation of the urea N caused a significant increase in: total N uptake, atom percent ^{15}N in the plant tissue, and total fertilizer N uptake.

In 1983, although differences were not statistically significant, plant responses to fertilizer placement were exactly the opposite in the microplots as compared to the main plots in which they were located. Plants in microplots, where fertilizer N had been applied on the soil surface, continued to grow during the early dry season while the surrounding plants in the main plots remained stunted from an apparent insufficient supply of moisture and/or N. The only apparent explanation for this difference is improved soil moisture conductivity in and around the microplots. Soil moisture conservation at spring planting time can be very critical to early crop emergence and uniform maturity in dry seasons in interior Alaska (Knight and Lewis, 1986). At the time of fertilization and planting, a certain amount of increased foot traffic and smoothing and packing was unavoidable in and around the microplot areas as a result of placing the plywood tray over the microplots during main plot fertilization, hand fertilizing, and soil sampling. Although the entire plot area was uniformly tilled and seeded with tractor-drawn implements, increased compaction in the microplot areas may have improved the soil moisture conductivity in that area enough to allow those plants to become established quicker, develop larger root systems, and take up enough soil N to maintain growth better than the crops around them until rain leached the surface-applied N into the root zone. Hence, in 1983, although the differences were not statistically significant, crops in the microplots where the N fertilizer had been placed on the soil surface showed increased plant growth, increased N concentration in the plant tissue, and increased plant uptake. Plants receiving surface-applied N in the main plots showed the exact opposite results.

In 1984, moisture was plentiful throughout the growing season and results of all plant N analyses were higher where fertilizer had been placed on the soil surface as opposed to where it had been incorporated. Plant growth and fertilizer N uptake were both significantly increased where the N fertilizer had been applied on the soil surface. A comparison of Figures 11 and 12 show that ammonium-N disappeared from the soil in the main plots much more rapidly where the urea had been incorporated than where it had been applied on the soil surface in 1984. Table 21 (Appendix) shows that the same thing occurred in the microplots. Incorporation of the N fertilizer apparently contributed to the rapid disappearance of ammonium from the soil by improving conditions favorable for immobilization of ammonium-N by soil microbes, or rapid nitrification followed by subsequent immobilization, leaching, or denitrification, any of which might have occurred under the wet soil conditions.

Actual fertilizer N uptake in the microplots was determined by the Isotope Dilution Method where the percent of fertilizer recovered from plant samples was calculated by Eq. [5] (Hauck and Bremner, 1976).

[5]
$$X = \frac{(TN)(c-b)}{a}$$

In this equation, **X** is the quantity (kg/ha) of labeled fertilizer N in the plants or soil, **TN** is the total amount of N (kg/ha) in the plants or soil, **a** is the excess atom % ^{15}N in the fertilizer, and **b** and **c** are the ^{15}N contents expressed as atom % in the standard (natural abundance) and in the sample, respectively. For this study, **a** = 5.0000-0.3660 = 4.6340; and **b** = 0.3757 for soil in all years, and 0.3857, 0.4120, and 0.3800 for plants in the years, 1982, 1983, and 1984, respectively. The figure, 0.3660, used in calculating **a** is the percentage of N in the atmosphere that is naturally in the form of ^{15}N (Hauck and Bremner, 1976), or as in this case, the percentage of N in unlabeled fertilizer that is naturally in the ^{15}N form. The **b** value of 0.3757 is an average of the percentages of ^{15}N in soil samples from zero-N plots during the three years of this study. This value remained fairly constant (SE = 0.0011) and did not differ significantly among years or among sampling dates within years.

Table 5 compares urea fertilizer N recovery rates by plants in the main plots and microplots. By the Difference Method, fertilizer N use efficiency during the year of fertilizer application would be estimated at 62.4%, 64.6% and 53.7% when determined for the main plots, and 62.1%, 50.1% and 55.3% when determined for the microplots for the 1982, 1983 and 1984 growing seasons, respectively. By the Isotope Dilution Method, however, one would conclude that only 45.1%, 33.1% and 40.7% of the fertilizer N was used by plants during the year of fertilizer application for the 1982, 1983 and 1984 growing seasons, respectively. These values show that barley plants in N-fertilized microplots

Table 5. Nitrogen uptake by plants in urea-fertilized plots in excess of that taken up in zero-N plots.

Nitrogen form measured	**Fertilizer treatment**	**1982 (kg N/ha)**	**1983 (kg N/ha)**	**1984 (kg N/ha)**
Total plant N in main plots	Urea (Inc.)	69.0	71.4	48.3
	Urea (Surf.)	55.9	57.8	59.0
	Avg.	**62.4**	**64.6**	**53.7**
Total plant N in microplots	Urea (Inc.)	67.7	46.2	39.3
	Urea (Surf.)	56.6	53.9	71.3
	Avg.	**62.1**	**50.1**	**55.3**
^{15}N labeled plant N in microplots	Urea (Inc.)	50.6	31.7	34.1
	Urea (Surf.)	39.5	34.4	47.2
	Avg.	**45.1**	**33.1**	**40.7**

took up an average of 55.8 kg more N per ha than in zero-N microplots, and only an average of 39.6 kg N/ha could be traced to the ^{15}N labeled fertilizer source. The difference, 16.2 kg N/ha, that was not from the fertilizer source, but which was obviously taken up by the plants as a result of the N fertilization, is a common phenomenon in fertilizer studies which is often called a priming effect. A subject much discussed in the literature, a priming effect is most likely caused by a combination of factors but generally assumed to result mainly from the following two phenomena: a) N-fertilized plants have more healthy root systems and are capable of exploring larger soil areas and more thoroughly extracting soil nutrients than nonfertilized plants, and b) the sudden large pool of inorganic labeled N in the soil from a fertilizer application increases the turnover rate whereby labeled N is immobilized and nonlabeled N is mineralized, resulting in a larger pool of unlabeled N for plant use (Jenkinson *et al.*, 1985).

<u>Soil Nitrogen in ^{15}N Microplots</u>

Significant interactions between sampling dates and fertilizer treatments were usually found in microplot soil samples when comparing: the concentrations of ammonium N, nitrate N, and total N in the soil; the atom percent ^{15}N in each of these N pools; and the quantities of N that could be traced back to the fertilizer source in each of these pools

(Table 20, Appendix). This significant interaction merely shows that soon after application the fertilizer had a significant impact on several of the soil N pools. However, as the growing season progressed, plant uptake removed much of the fertilizer N from the soil, and soil microbes immobilized most of the remaining fertilizer N. Hence, by the end of the growing season, fertilizer treatments no longer had a significant effect on many of the soil N pools. Where significant interactions were found, the interaction means were separated by the BLSD test to determine which fertilizer treatments on which sampling dates contributed significantly to the variation in the N pools (Table 21, Appendix).

Concentrations of ammonium and nitrate were very low in soil samples collected below 15 cm depth. The atom percent ^{15}N in these samples was also low and erratic, and was not significantly different from the natural abundance of ^{15}N in the soil. Thus, the atom percent ^{15}N in the forms of ammonium and nitrate, and the corresponding quantities of fertilizer N represented by this percentage, are only reported for the 0-15 cm soil depth (Table 21, Appendix). In the total N pool, concentrations of N were much higher. Therefore, labeled N in this pool was reported to the 45-cm depth. Quantities of fertilizer N detected in the soil ammonium, nitrate, and total N pools are shown in Figure 15.

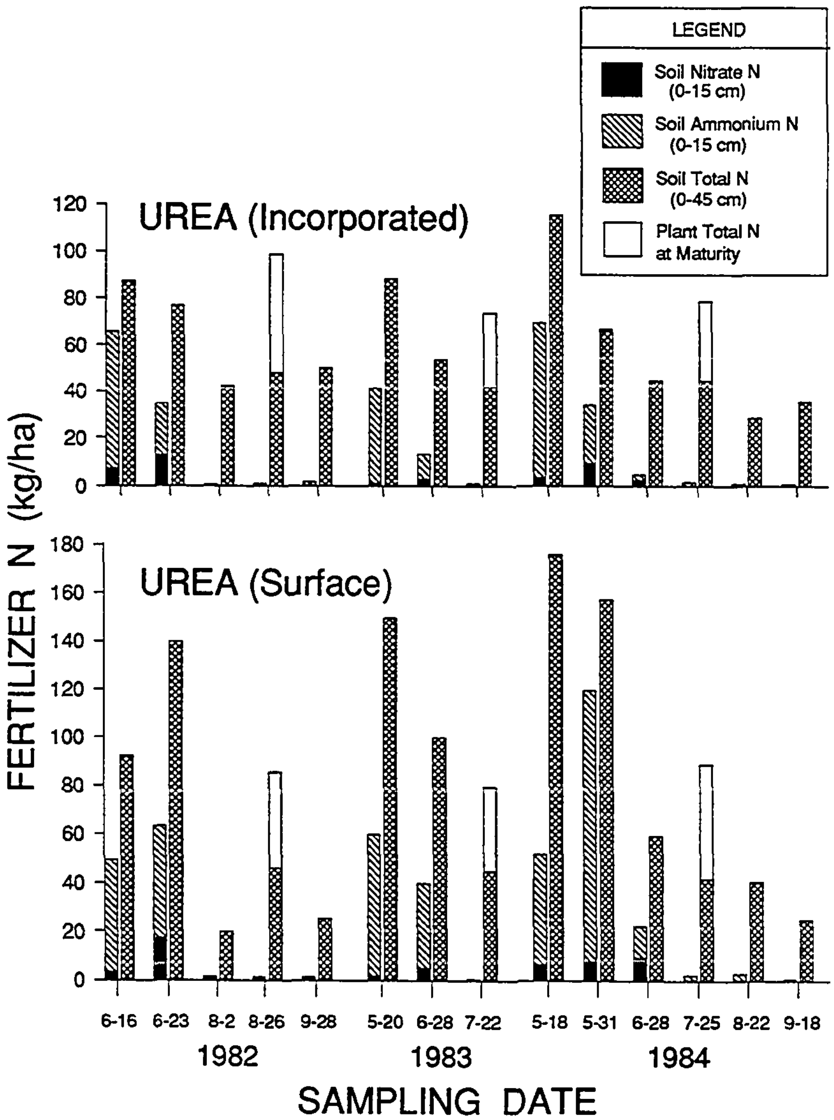

Figure 15. Fertilizer nitrogen detected in soil ammonium, nitrate, and total N pools on each sampling date; and in barley plants at physiological maturity.

Two bars are graphed in Figure 15 for each sampling date. The first bar shows the fertilizer N detected in the inorganic (ammonium + nitrate) pool at the 0-15 cm soil depth, and the second bar shows fertilizer N detected in the soil total N (inorganic + organic) pool at the 0-45 cm sampling depth. Thus, the difference between the two bars on each date indicates the fraction of fertilizer N that had either become immobilized in the soil or had moved down below the 15-cm soil depth. Quantities of fertilizer N detected in the barley plants at physiological maturity are also plotted in Figure 15, showing a cumulative value for all fertilizer N pools measured on those dates.

Fertilizer N recovery rates of greater than 100 percent were often obtained from soil samples on the first one or two sampling dates each year, particularly were the urea was applied on the soil surface. This excessive recovery rate apparently resulted from uneven fertilizer distribution in the microplots. Although an attempt was made to spread the labeled urea uniformly over the microplot area, it appears that the microplots may have been over-fertilized near the centers (where the soil samples were taken) and under-fertilized near the edges. In microplots where the urea was incorporated, hand tillage aided in distributing the fertilizer more uniformly and early-season soil N recovery rates from those plots appear more reasonable.

This problem of uniform fertilizer distribution in field study microplots is not uncommon and some researchers have gone to the extreme of removing all of the surface soil from field microplots, thoroughly mixing the fertilizer with the soil, and returning the soil to the field to achieve uniform fertilizer distribution, then repeating this process at harvest time for uniform soil sampling (Carter *et al.*, 1967). Spacial relationships of soil N are quite variable, and one must compromise between adequate sampling and excessive disturbance of natural soil conditions. Considerable discussion about soil N spacial relationships and soil sampling techniques can be found in the literature (Broadbent *et al.*, 1980; Pratt *et al.*, 1976; Rible *et al.* 1976). In this study, by the time the crop reached physiological maturity, plant roots had apparently explored the microplot area such that fertilizer N recovery rates at that time did not appear to be affected by fertilizer placement regardless of early-season recovery rates of soil N.

Net seasonal soil N mineralization was measured at 0, 9, and 11 kg N/ha in zero-N microplots for the three years of this study, averaging approximately 7 kg N/ha. Net seasonal fertilizer N immobilization was approximated from the quantity of labeled N detected in the organic fraction of the soil at crop maturity. The net seasonal fertilizer N immobilization remained fairly constant during the three years with a range from 46 to 41 and an average of 43 kg N/ha immobilized each season.

Fertilizer N Budget at Crop Physiological Maturity

Fertilizer N distribution at the time the barley reached physiological maturity (Table 6) was determined by the Isotope Dilution Method using ^{15}N labeled urea. Recovery of fertilizer N averaged 84 percent for the three

Table 6. Fertilizer N budget at physiological maturity of barley crop.

Year	Fertilizer Treatment (kg N/ha)	Soil NH_4^+-N 0-15 cm (kg/ha)	Soil NO_3^--N 0-15 cm (kg/ha)	Soil† Organic N 0-45 cm (kg/ha)	Total Plant N (kg/ha)	Total Recovered Fertilizer N (kg/ha)
1982	100 inc.	0.9	0.1	46.8	50.6 b	98.4
	100 surf.	0.7	0.7	44.5	39.5 a	85.4
	BLSD	**NS** *	**NS**	**NS**	**6.2**	**NS**
1983	100 inc.	1.0	0.1	40.6	31.7	73.5
	100 surf.	0.4	0.1	44.4	34.4	79.4
		NS	**NS**	**NS**	**NS**	**NS**
1984	100 inc.	1.6	0.1	42.8	34.1 a	78.6
	100 surf.	2.1	0.2	39.5	47.24 b	89.0
	BLSD	**NS**	**NS**	**NS**	**9.0**	**NS**
Means:	inc.	1.2	0.1	43.4	38.8	83.5
	surf.	1.1	0.4	42.8	40.4	84.6
		NS	**NS**	**NS**	**NS**	**NS**
	1982	0.8 a	0.4	45.7	45.1 b‡	91.9
	1983	0.7 a	0.1	42.5	33.1 a	76.4
	1984	1.8 b	0.2	41.2	40.7 b	83.8
	BLSD	1.0	**NS**	**NS**	7.5	**NS**

† Total soil N minus the ammonium-N and nitrate-N identified in the 0-15 cm soil layer.
* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Different test (BLSD). NS indicates not significant.
‡ Significant interaction among years and N-fertilizer placement.

years of this study. This recovery rate is well within the normal range (66 to 99 percent) of published results (Campbell and Paul, 1978; Jones *et al.*, 1981; Smith *et al.*, 1982). Fertilizer N uptake by plants during the three years of this study ranged from 33 to 45 percent, slightly below the average reported value of approximately 50 percent (Cameron and Hayes, 1986), but well within the normally reported range of 30 to 70 percent for plant recovery during the year of application (Campbell and Paul, 1978; Christensen and Killorn, 1981, Nyborg, 1983). The lowest crop uptake of fertilizer N, and the lowest recovery of fertilizer N, both occurred in 1983 when the soil was dry during the early growing season. This dry period corresponded with the time that the greatest quantity of inorganic N was present in the soil and thus most susceptible to N loss, and the stage of growth at which plants take up most of their N (Campbell *et al.*, 1977).

An average of 43 percent of the fertilizer N remained in the soil at the time of crop maturity. Of this soil N, only approximately three percent was in an available (ammonium or nitrate) form, and the rest had been immobilized. Campbell *et al.* (1978), comparing dryland to irrigated conditions, reported that a considerable proportion (28-57 percent) of fertilizer N remained in the soil under dryland conditions.

An average of only 16 percent of the fertilizer N remained unaccounted for each year at crop maturity. Part of this fraction may be explained by sampling error, but this probably represents a fairly accurate estimate of fertilizer loss via denitrification, slight leaching, or undetected volatilization. The greatest loss occurred during the dry season of 1983 when leaching should have been minimal. Soil moisture tension was always high at some depth in the soil profile and never indicated any period of significant moisture flow during that growing season. Also, losses during 1983 and 1984 were greater where the fertilizer had been incorporated as opposed to where it had been left on the soil surface where it should have been more susceptible to volatilization. Hence, denitrification appears to be the most logical explanation for the unaccountable fertilizer N losses. There is much discussion in the literature seeking to explain the reasons for denitrification in seemingly well aerated soils. A review by Broadbent and Clark (1965) indicates that even in well aerated soils, losses of fertilizer N by denitrification are often reported in the order of 10 to 30 percent.

Grain Yields

Grain yields were compared by ANOVA each year (Table 22, Appendix). In 1982 there were no significant differences in yields among the fertilizer applications, apparently a result of an adequate supply of mineralized nitrogen being supplied by the soil for the first year of the study. Fertilizer N did have a significant effect on yields in the two subsequent years. Yield means for each of those years were compared by the BLSD test (Table 23, Appendix) and yields for all three years were plotted in Figure 16.

In 1983, zero-N treatments yielded significantly less than N-fertilized treatments, but there were no significant

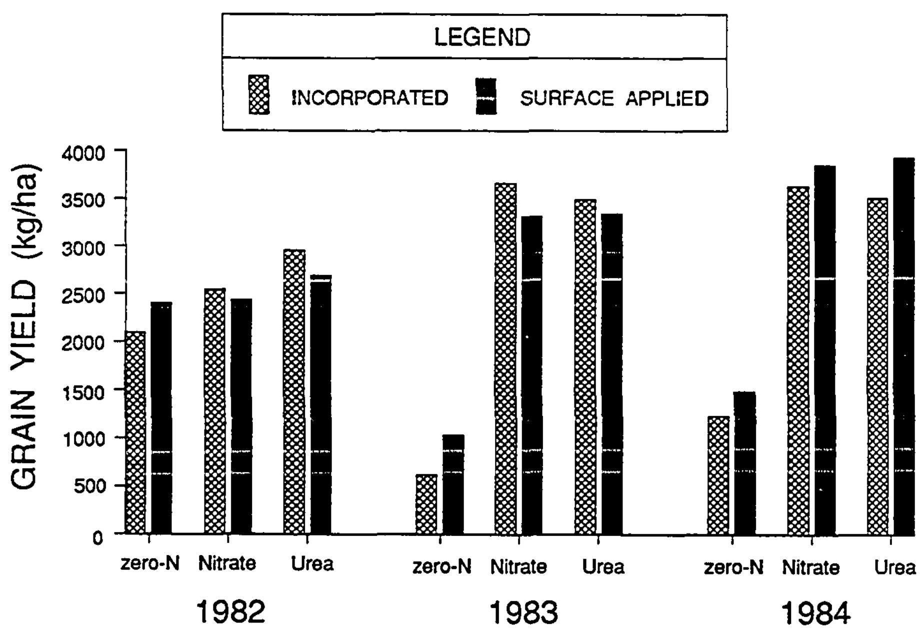

Figure 16. Grain yields, 1982-1984.

differences among N-fertilized treatments regardless of N source or position of placement. In 1984, grain yields were, again, less in zero-N plots than in N-fertilized plots. In this year, however, grain yields were significantly affected by fertilizer placement. N-fertilizer incorporation resulted in reduced grain yields for both fertilizer materials. However, the effect was statistically significant ($P \leq 0.05$) for only the urea treatments.

Although differences in grain yields, as affected by N-fertilizer placement, were small each year and were significant only in the wet season of 1984, it is noteworthy that yields were slightly increased by incorporation of both N sources in 1982 and 1983 and slightly decreased in 1984. In both, 1982 and 1983, there was some indication that surface-applied N fertilizers were slower to nitrify and were not readily available for plant uptake until sufficient rain was received to leach the N into the soil. Early availability of N may explain the slightly higher grain yields from incorporated fertilizers in those two years. In 1984, however, precipitation came rapidly enough during the early season to not only leach N down into the soil, but also, to possibly leach nitrate out of the root zone, and to create moist conditions in the soil favorable for N immobilization and possibly denitrification. In 1984, surface application of N fertilizers may have been beneficial in reducing early N immobilization or losses of fertilizer N due to denitrification or leaching. Since lower yields in 1984 were noted in the incorporated plots of calcium nitrate as well as urea, a delay in the rate of nitrification of N from the urea source does not appear to explain yield differences resulting from the position of placement of the fertilizer materials. Denitrification, therefore, appears to be the best explanation for the lower fertilizer N recovery rates and lower grain yields in plots where the N fertilizer had been incorporated in 1984. In 1982 and 1983, the soil was dryer and the rate of denitrification should have been slower than in 1984. Grain yields were greater in those two years where the N fertilizer was incorporated into the root zone. However, in 1983 fertilizer N losses were also greater than in either of the other two years. Although denitrification would not be expected to occur as rapidly in a dry year, it may still be responsible for a majority of the N loss in 1983 because slow plant growth from insufficient moisture resulted in a large quantity of available nitrogen lying in the soil for an extended period, that spring, during which denitrification in microsites may have been significant.

SYNOPSIS

This study is unique in that it is the first major attempt in Alaska to trace fertilizer N in a cultivated soil, to determine how much of the N is used by the crop, and to determine what happens to the remainder of it. Previous studies have compared crop responses to N fertilizer applications, but this is the first study in Alaska to use ^{15}N to identify fertilizer N in the various N pools. No other studies have attempted to measure ammonia volatilization from an Alaskan agricultural soil, and only one other study has used deep soil cores to evaluate nitrate leaching below the 15-cm depth as a result of agricultural fertilizer applications (Knight and Lewis, 1981).

When this study was initiated, we had little information on the primary controls of nitrogen cycling in this type of ecosystem and could only speculate about which nitrogen transformations were prominent in determining the fate of fertilizer N. Consequently, this study was designed to provide a broad overview of what pools the fertilizer N is in at the end of the growing season, and how it got into each pool. Considerable insight was gained in this area. Not only did this study account for an average of 84 percent of the fertilizer N by the end of each season, but it identified areas where additional research is likely to be most productive.

We determined that an average of 43 percent of the applied N was immobilized in the soil during the year of application. Much of this immobilized N will likely be remineralized, eventually, and depending on the time of year and conditions under which this occurs, may be available for uptake by subsequent crops or may be a potential source of ground-water pollution. As a follow-up on this question, plant and soil samples have been collected from the microplots for the second and third years following the ^{15}N applications. These soil samples are presently being prepared for analysis in an attempt to measure the rate of disappearance of immobilized fertilizer N from the soil and determine how much of it is utilized by the crop.

Nitrification and crop uptake were confounded in this study and it was unclear whether N from the urea source was taken up by the plants primarily in the ammonium form or if it nitrified first and was absorbed as nitrate. More nitrogen was taken up by the crop from the calcium nitrate source than from the urea source. There are several possible explanations for this difference. Nitrate is more mobile than ammonium in the soil and can move into the root zone by mass flow. Also, some researchers report that soil microbes immobilize ammonium N much more readily than nitrate N leaving less ammonium N available for crop use. A better understanding of the form of N taken up by the plants following urea applications would be very valuable in making management decisions to improve the efficiency of urea use by the crop.

Very little leaching was measured during the growing seasons. Concentrations of soil nitrate and soil moisture were often low during the growing season, and previous studies have shown that net soil moisture movement is probably upward during most of this period. A gradual increase in nitrate at lower depths in N-fertilized plots, however, leads one to speculate that nitrification and subsequent leaching may be much more prominent during spring and autumn when no crop is present. A more intense study of leaching during these seasons would be valuable in further defining the possible impact of fertilizer N on ground-water pollution.

Soil temperatures were cool at planting time but did not vary greatly among years or fertilizer treatments. Urea hydrolysis appeared to be rapid each year, and ammonia volatilization did not appear to be a reason for major concern in this type of cropping system. Soil moisture content had a great effect on crop growth and on the rate of disappearance of fertilizer N from the soil. High soil moisture tensions were recorded in two of the three growing seasons. Irrigation during dry seasons would likely enhance crop growth and would ensure early crop maturity, particularly when fertilizer is placed on the soil surface.

SUMMARY AND CONCLUSIONS

Summary

Several previous reports have indicated that N fertilizer in the form of nitrate is superior to urea in promoting crop response in Alaska. Researchers have speculated that such differences may result from: volatilization losses of ammonia N following urea application, delayed urea hydrolysis due to cold and/or acid soils, or delayed nitrification of ammonium N from urea coupled with a possible crop preference for nitrate N as opposed to ammonium N.

In this three-year study in interior Alaska, there were no differences in grain yields of spring barley among plots fertilized with either urea or calcium nitrate. The amount of N taken up by barley plants was affected by N source. On most sampling dates, barley plants which had been fertilized with calcium nitrate showed greater production of dry matter and contained a higher concentration of N in the plant tissue than plants that had been fertilized with urea. Since the calcium nitrate fertilizer was not enriched with ^{15}N, it was not possible to verify that the additional N taken up in the calcium nitrate plots came from the fertilizer source. However, the greater plant uptake of nitrate N may be a result of either, greater mobility of nitrate ions allowing them to move to plants by mass flow, or greater immobilization of the ammonium N, released during urea hydrolysis, causing less urea N to be readily available for plant use.

Cool weather and moist soils at the time of spring planting did not create conditions favorable for ammonia volatilization, and losses measured by this mechanism appeared negligible even when the N fertilizer was applied on the soil surface. Urea hydrolysis was rapid and only traces of urea were found in the soil two weeks following fertilizer application. Thus, the rate of urea hydrolysis was not considered to be a limiting factor in affecting N availability to the barley crop.

Although there were a few indications of nitrate leaching during heavy rains, there was very little nitrate in the soil during the growing season except for a short time following fertilizer application. Also, soil moisture tension remained high enough during two of the three seasons that water movement down through the soil profile appeared unlikely. The greatest potential for leaching of fertilizer N is likely to occur in autumn, after the crop is mature, and before the soil freezes. At that time, immobilized fertilizer N may be remineralized and leached by autumn precipitation or forced downward ahead of the soil freezing front by ion exclusion.

Fertilizer N use efficiency by barley during the season of application was determined by the Difference Method in both the main plots and the microplots, and by the Isotope Dilution Method in the microplots. In the main plots, average seasonal fertilizer N use efficiencies of 73 and 60 percent were indicated for the calcium nitrate and urea fertilizers, respectively. In the urea microplots, an average fertilizer N use efficiency of 56 percent was determined by the Difference Method and 40 percent by the Isotope Dilution Method. Since plants in urea-fertilized microplots took up an average of 56 kg/ha more N than plants in zero-N microplots, but since only 40 kg of that N could be traced to the fertilizer source, the 16 kg N/ha difference was explained by the "priming effect" i.e. N turnover between soil organic and inorganic pools, and enlarged root systems of N-fertilized plants.

Net seasonal N mineralization from soil was estimated from crop uptake of N in zero-N plots. Three year averages of soil N mineralization were 7 kg N/ha in the microplots and 14 kg N/ha in the main plots.

Net seasonal immobilization of N from the urea fertilizer source was estimated from the quantity of labeled N detected in the organic fraction of the soil at crop maturity. Net seasonal fertilizer N immobilization averaged 43 kg N/ha and did not vary significantly from year to year.

The effects of N-fertilizer placement varied from year to year with respect to the time and quantity of precipitation received. Grain yields were not greatly affected by the placement of N fertilizer in any year, but crop maturity was obviously affected in 1983 when barley maturity was delayed approximately two weeks in plots where the fertilizer had been applied on the soil surface. Since the growing season is short in interior Alaska and yields are often reduced by early frosts and snowfall, early crop maturity can be critical in ensuring a successful crop. Hence, N-fertilizer incorporation appears justified, if for on other reason than its enhancement of early crop uptake and early crop maturity. Fertilizer N losses were greater in two years and less in one year where the N fertilizer had been incorporated versus surface applied. Losses during the growing season were not great, however, and an average of only 16 percent of the fertilizer N could not be detected at physiological maturity. Denitrification appeared to be the logical explanation for this loss.

Soil moisture tensions high enough to cause crop stress were recorded in two of the three growing seasons. This observation reinforces the need for the use of good soil moisture management practices in spring barley production in interior Alaska.

Conclusions

Fertilizer N cycling in a subarctic agricultural soil does not appear to differ greatly from fertilizer N cycling in more temperate areas. Urea N use efficiency was near the lower end of the normal range reported in the literature, but most of the unused fertilizer N was not lost from the system and remained immobilized in the soil at the end of the growing season. Urea did not appear inferior to calcium nitrate in the production of barley grain, but the crop did take up greater quantities of N and dry matter production was higher when fertilized with calcium nitrate. Therefore, fertilization with a nitrate form of N compared to an equal rate of N in the form of urea may result in improved quality of barley grain and/or straw.

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APPENDIX

(ANOVA and Mean Separation Tables)

Table 7. ANOVA tables of soil moisture tension from buried gypsum blocks.

Source	df†	SS	MS	F
1982 (all depths)				
Block (B)	2	2403992	1201996	1.82
Treatment (T)	2	10839269	5419634	8.23 *
TxB (error 1)	4	2634932	658733	
Depth (D)	4	18019204	4504801	8.45 *
DxB (error 2)	8	4262376	532797	
DxT	8	8796782	1099597	3.02 *
DxTxB (error 3)	16	5824148	364009	
Sampling date (D)	7	33502436	4786062	56.24 *
SxT	14	14803934	1057423	12.43 *
SxD	26	36306717	1396412	16.40 *
SxTxD	52	16647772	320149	3.76 *
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	195	16597187	85113	
1983 (all depths)				
Block (B)	2	953959	476979	5.50
Treatment (T)	2	1161839	580919	6.69
TxB (error 1)	4	347388	86847	
Depth (D)	4	1290549	322637	2.66
DxB (error 2)	8	969745	121218	
DxT	8	2348143	293517	1.52
DxTxB (error 3)	11	2120930	192811	
Sampling date (D)	11	13602748	1236613	35.23 *
SxT	22	7502238	341010	9.72 *
SxD	37	18923104	511435	14.57 *
SxTxD	68	10382292	152680	4.35 *
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	168	5900996	35124	
1984 (all depths)				
Block (B)	2	6870	3435	0.83
Treatment (T)	2	630	315	0.07
TxB (error 1)	3	12246	4082	
Depth (D)	4	16041	4010	3.64
DxB (error 2)	8	8457	1057	
DxT	8	7873	984	0.45
DxTxB (error 3)	10	21756	2175	
Sampling date (D)	10	15022	1502	16.68 *
SxT	20	3679	183	2.04 *
SxD	36	18455	512	5.69 *
SxTxD	70	7108	101	1.13
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	201	18101	90	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 7 Continued. ANOVA tables of soil moisture tension from buried gypsum blocks.

Source	df†	SS	MS	F
1982 5-cm depth				
Block (B)	2	88657	44328	3.97
Treatment (T)	2	3004411	1502205	134.41 *
BxT (error 1)	4	44704	11176	
Sampling date (S)	6	25032536	4172089	609.75 *
SxT	12	10259449	854954	124.95 *
SxB + SxTxB (error 2)	36	246321	6842	
1982 15-cm depth				
Block (B)	2	664170	332085	1.90
Treatment (T)	2	9027641	4513820	25.87 *
BxT (error 1)	4	697833	174458	
Sampling date (S)	6	33189660	5531610	46.74 *
SxT	12	15495072	1291256	10.91 *
SxB + SxTxB (error 2)	36	4260608	118350	
1982 50-cm depth				
Block (B)	2	6053068	3026534	1.54
Treatment (T)	2	8208153	4104076	2.08
BxT (error 1)	4	7875971	1968992	
Sampling date (S)	7	12536358	1790908	6.25 *
SxT	14	6289833	449273	1.57 *
SxB + SxTxB (error 2)	42	12033991	286523	
1982 100-cm depth				
Block (B)	2	964	482	0.07
Treatment (T)	2	20774	10387	1.46
BxT (error 1)	4	28457	7114	
Sampling date (S)	7	25787	3683	2.78 *
SxT	14	20781	1484	1.12
SxB + SxTxB (error 2)	42	55751	1327	
1982 150-cm depth				
Block (B)	2	2219	1109	1.55
Treatment (T)	2	988	494	0.72
BxT (error 1)	4	2600	650	
Sampling date (S)	7	2030	290	21.99 *
SxT	14	150	10	0.81
SxB + SxTxB (error 2)	39	514	13	
1983 5-cm depth				
Block (B)	2	473851	236925	0.14
Treatment (T)	2	1164694	582347	11.87 *
BxT (error 1)	4	468128	117032	
Sampling date (S)	10	15565186	1556518	55.28 *
SxT	20	9643708	482185	17.13 *
SxB + SxTxB (error 2)	38	1069957	28156	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 7 Continued. ANOVA tables of soil moisture tension from buried gypsum blocks.

Source	df†	SS	MS	F
1983 15-cm depth				
Block (B)	2	357427	178713	1.42
Treatment (T)	2	803081	401540	1.47
BxT (error 1)	4	397960	99490	
Sampling date (S)	10	11463863	1146386	10.07 *
SxT	19	6105481	321341	2.82 *
SxB + SxTxB (error 2)	29	3302368	113874	
1983 50-cm depth				
Block (B)	2	99134	49567	1.20
Treatment (T)	2	117500	58750	1.72
BxT (error 1)	3	63626	21208	
Sampling date (S)	10	283271	28327	1.54
SxT	18	666824	37045	2.02 *
SxB + SxTxB (error 2)	35	643418	18383	
1983 100-cm depth				
Block (B)	2	310676	155338	0.78
Treatment (T)	2	1398962	699481	1.28
BxT (error 1)	2	2319671	1159835	
Sampling date (S)	9	251456	27939	0.92
SxT	18	634355	35241	1.16
SxB + SxTxB (error 2)	29	882574	30433	
1983 150-cm depth				
Block (B)	2	1741	870	0.40
Treatment (T)	2	3135	1567	0.92
BxT (error 1)	3	5335	1778	
Sampling date (S)	9	1449	161	2.23 *
SxT	15	1849	123	1.70
SxB + SxTxB (error 2)	37	2676	72	
1984 5-cm depth				
Block (B)	2	4119	2059	0.91
Treatment (T)	2	343	171	0.06
BxT (error 1)	3	6349	2116	
Sampling date (S)	10	15116	1511	25.20 *
SxT	20	2280	114	1.90 *
SxB + SxTxB (error 2)	48	2879	59	
1984 15-cm depth				
Block (B)	2	9335	4667	0.62
Treatment (T)	2	560	280	0.03
BxT (error 1)	3	23459	7819	
Sampling date (S)	10	10517	1051	6.12 *
SxT	20	3729	186	1.09
SxB + SxTxB (error 2)	47	8072	171	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 7 Continued. ANOVA tables of soil moisture tension from buried gypsum blocks.

Source	df†	SS	MS	F
1984 50-cm depth				
Block (B)	2	3089	1544	2.34
Treatment (T)	2	1832	916	4.34
BxT (error 1)	2	422	211	
Sampling date (S)	9	5086	565	8.79 *
SxT	18	1515	84	1.31
SxB + SxTxB (error 2)	36	2314	64	
1984 100-cm depth				
Block (B)	2	692	346	0.28
Treatment (T)	2	8712	3906	1.69
BxT (error 1)	2	4772	2386	
Sampling date (S)	9	2893	321	8.51 *
SxT	18	1241	68	1.83
SxB + SxTxB (error 2)	35	1322	37	
1984 150-cm depth				
Block (B)	2	1218	609	1.12
Treatment (T)	2	832	416	0.77
BxT (error 1)	3	1672	557	
Sampling date (S)	8	2429	303	3.03 *
SxT	14	1816	129	1.29
SxB + SxTxB (error 2)	35	3512	100	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 8. Mean separations of soil moisture tension (kPa) at five soil depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1982						
all	Zero-N	70	51	58	29	31
all	$Ca(NO_3)_2$	567	934	661	65	24
all	Urea	490	738	850	28	22
		INT *	INT	INT	INT	INT
29 JUN	all	44	24	27	23	27
14 JUL	all	42	153	39	24	24
28 JUL	all	116	135	50	20	21
17 AUG	all	302	1544	1016	30	20
01 SEP	all	1906	1878	1092	52	22
16 SEP	all	77	109	862	47	24
01 OCT	all	142	178	597	78	30
13 OCT	all			504	54	38
		INT	INT	INT	INT	INT
29 JUN	Zero-N	52 a	22 a	28 a	23 a	35 gh
29 JUN	$Ca(NO_3)_2$	35 a	29 a	20 a	25 a	22 abcde
29 JUN	Urea	45 a	21 a	32 a	20 a	29 cdefg
14 JUL	Zero-N	19 a	22 a	39 a	25 a	31 efgh
14 JUL	$Ca(NO_3)_2$	48 a	333 a	28 a	27 a	20 abcd
14 JUL	Urea	60 a	105 a	50 a	21 a	21 abcde
28 JUL	Zero-N	47 a	26 a	46 a	20 a	28 bcdefg
28 JUL	$Ca(NO_3)_2$	212 bc	310 a	46 a	24 a	20 abcd
28 JUL	Urea	88 a	69 a	57 a	16 a	16 a
17 AUG	Zero-N	59 a	72 a	75 a	25 a	26 abcdefg
17 AUG	$Ca(NO_3)_2$	533 d	2611 c	1369 cde	47 a	19 abcd
17 AUG	Urea	313 c	1950 b	1605 e	16 a	16 a
01 SEP	Zero-N	220 bc	135 a	76 a	30 a	27 bcdefg
01 SEP	$Ca(NO_3)_2$	2777 e	2777 c	1339 bcde	93 ab	23 abcdef
01 SEP	Urea	2722 e	2722 c	1862 e	34 a	17 ab
16 SEP	Zero-N	44 a	38 a	64 a	31 a	29 defg
16 SEP	$Ca(NO_3)_2$	107 ab	170 a	1014 abcd	76 ab	23 abcdef
16 SEP	Urea	80 a	118 a	1508 de	33 a	18 abc
01 OCT	Zero-N	49 a	44 a	66 a	38 a	33 fgh
01 OCT	$Ca(NO_3)_2$	256 c	307 a	805 ab	155 b	31 efgh
01 OCT	Urea	120 ab	182 a	918 abc	40 a	27 abcdefg
13 OCT	Zero-N			72 a	44 a	41 h
13 OCT	$Ca(NO_3)_2$			669 a	73 ab	36 gh
13 OCT	Urea			770 a	45 a	35 gh
	BLSD	122	545	1272	99	11

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 8 Continued. Mean separations of soil moisture tension (kPa) at five soil depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1983						
all	Zero-N	53	45	50	34	41
all	$Ca(NO_3)_2$	381	320	147	351	28
all	Urea	277	188	145	17	25
	BLSD	INT *	INT	INT	INT	INT
26 APR	all	43	20			
04 MAY	all	38	33	74		
11 MAY	all	71	32			
01 JUN	all	81	38	51	204	28
14 JUN	all	1636	1504	49	72	49
28 JUN	all	42	34	55	339	34
13 JUL	all	65	48	277	32	30
27 JUL	all	107	79	119	32	30
10 AUG	all	225	110	122	39	30
23 AUG	all	43	36	130	48	32
07 SEP	all	30	24	97	39	29
22 SEP	all			83	40	31
05 OCT	all			72	37	29
		INT	INT	INT	INT	INT
26 APR	Zero-N	19 a	18 a			
26 APR	$Ca(NO_3)_2$	25 a	23 a			
26 APR	Urea	78 a				
04 MAY	Zero-N	31 a	29 a			
04 MAY	$Ca(NO_3)_2$	41 a	48 a	110 a		
04 MAY	Urea	42 a	27 a	38 a		
11 MAY	Zero-N	57 a	45 a			
11 MAY	$Ca(NO_3)_2$	70 a	25 a			
11 MAY	Urea	93 a	25 a			
01 JUN	Zero-N	64 a	48 a	54 a	41 a	
01 JUN	$Ca(NO_3)_2$	96 a	36 a	40 a	633 b	29 ab
01 JUN	Urea	91 a	31 a	56 a	20 a	
14 JUN	Zero-N	207 a	216 a	53 a	39 a	78 c
14 JUN	$Ca(NO_3)_2$	2917 d	2833 c	38 a	176 ab	29 ab
14 JUN	Urea	2500 c	1464 b	54 a	18 a	
28 JUN	Zero-N	26 a	26 a	53 a	38 a	44 b
28 JUN	$Ca(NO_3)_2$	55 a	38 a	41 a	1113 c	28 ab
28 JUN	Urea	52 a	37 a	70 a	18 a	28 ab
13 JUL	Zero-N	31 a	30 a	73 a	35 a	40 ab
13 JUL	$Ca(NO_3)_2$	81 a	57 a	116 a	68 a	27 ab
13 JUL	Urea	98 a	59 a	745 b	11 a	21 a
27 JUL	Zero-N	40 a	34 a	43 a	28 a	37 ab
27 JUL	$Ca(NO_3)_2$	178 a	101 a	241 a	82 a	27 ab
27 JUL	Urea	139 a	104 a	113 a	13 a	23 a

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 8 Continued. Mean separations of soil moisture tension (kPa) at five soil depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1983						
10 AUG	Zero-N	40 a *	34 a	44 a	32 a	36 ab
10 AUG	$Ca(NO_3)_2$	636 b	146 a	263 a	110 a	28 ab
10 AUG	Urea	92 a	149 a	99 a	15 a	23 a
23 AUG	Zero-N	31 a	25 a	48 a	35 a	39 ab
23 AUG	$Ca(NO_3)_2$	57 a	43 a	278 a	142 a	28 ab
23 AUG	Urea	49 a	41 a	107 a	22 a	29 ab
07 SEP	Zero-N	25 a	25 a	43 a	29 a	36 ab
07 SEP	$Ca(NO_3)_2$	35 a	25 a	195 a	119 a	27 ab
07 SEP	Urea	31 a	22 a	80 a	13 a	23 a
22 SEP	Zero-N			46 a	33 a	38 ab
22 SEP	$Ca(NO_3)_2$			148 a	99 a	29 ab
22 SEP	Urea			74 a	20 a	25 ab
05 OCT	Zero-N			40 a	29 a	38 ab
05 OCT	$Ca(NO_3)_2$			128 a	95 a	21 a
05 OCT	Urea			60 a	20 a	25 ab
	BLSD	254	651	293	479	20
1984						
all	Zero-N	37	36	38	27	31
all	$Ca(NO_3)_2$	40	31	54	42	23
all	Urea	41	28	52	13	28
		INT	INT	INT	INT	INT
16 MAY	all	45	38			
07 JUN	all	61	49	63	43	
13 JUN	all	18	15	60	36	21
28 JUN	all	30	26	50	32	41
12 JUL	all	28	22	49	29	29
25 JUL	all	24	22	41	26	22
08 AUG	all	44	35	43	22	30
22 AUG	all	56	46	47	25	26
05 SEP	all	30	22	34	17	20
18 SEP	all	47	42	39	24	27
02 OCT	all	49	40	41	23	25
		INT	INT	INT	INT	INT
16 MAY	Zero-N	46 defghij	57 cd			
16 MAY	$Ca(NO_3)_2$	51 efghijk	29 abcd			
16 MAY	Urea	36 bcdefg	28 abcd			
07 JUN	Zero-N	64 kl	66 d	50 cdefgh	35 ghij	
07 JUN	$Ca(NO_3)_2$	53 ghijkl	41 abcd	69 hij	60 l	
07 JUN	Urea	69 l	36 abcd	76 j	20 abcdef	
13 JUN	Zero-N	22 ab	19 ab	48 bcdefgh	36 hij	
13 JUN	$Ca(NO_3)_2$	19 ab	10 a	64 ghij	57 kl	21 abc
13 JUN	Urea	13 a	16 ab	72 ij	17 abcd	

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 8 Continued. Mean separations of soil moisture tension (kPa) at five soil depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1984						
28 JUN	Zero-N	25 ab*	23 abc	42 abcdef	33 fghij	42 bcd
28 JUN	$Ca(NO_3)_2$	36 bcdef	28 abcd	56 defghij	47 jk	29 abc
28 JUN	Urea	28 abc	26 abc	55 defghij	15 abcd	59 d
12 JUL	Zero-N	22 ab	21 abc	46 abcdefg	31 efghi	38 abcd
12 JUL	$Ca(NO_3)_2$	33 bcd	25 abc	59 fghij	43 ijk	25 abc
12 JUL	Urea	31 bcd	19 ab	45 abcdefg	11 abc	20 abc
25 JUL	Zero-N	19 ab	15 ab	27 a	20 abcdef	28 abc
25 JUL	$Ca(NO_3)_2$	28 abc	26 abc	59 fghij	41 ij	20 abc
25 JUL	Urea	26 ab	29 abcd	43 abcdefg	19 abcdef	15 a
08 AUG	Zero-N	36 bcdef	35 abcd	32 abc	21 abcdefg	28 abc
08 AUG	$Ca(NO_3)_2$	47 defghij	36 abcd	57 efghij	35 hij	22 abc
08 AUG	Urea	53 fghijkl	33 abcd	47 abcdefg	13 abcd	43 cd
22 AUG	Zero-N	45 defghi	47 abcd	35 abcd	24 cdefgh	29 abc
22 AUG	$Ca(NO_3)_2$	62 ijkl	46 abcd	60 fghij	36 hij	24 abc
22 AUG	Urea	63 jkl	46 abcd	51 cdefghi	15 abcd	24 abc
05 SEP	Zero-N	26 ab	23 abc	29 ab	18 abcde	24 abc
05 SEP	$Ca(NO_3)_2$	31 bcd	22 abc	38 abcde	23 bcdefgh	17 ab
05 SEP	Urea	35 bcde	19 ab	40 abcdef	10 ab	18 abc
18 SEP	Zero-N	52 efghijk	49 bcd	35 abcd	25 defgh	31 abc
18 SEP	$Ca(NO_3)_2$	43 cdefgh	43 abcd	40 abcdef	36 hij	25 abc
18 SEP	Urea	46 defghij	30 abcd	45 abcdefg	10 abc	23 abc
02 OCT	Zero-N	55 hijkl	52 bcd	37 abcde	26 defgh	30 abc
02 OCT	$Ca(NO_3)_2$	44 cdefgh	33 abcd	42 abcdef	34 ghij	22 abc
02 OCT	Urea	47 defghijk	32 abcd	47 abcdefg	8 a	21 abc
	BLSD	17	38	21	14	26

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD).

Table 9. ANOVA tables of soil temperatures from buried thermisters.

Source	df†	SS	MS	F
1982 (all depths)				
Block (B)	2	19.5	9.7	6.96 *
Treatment (T)	2	40.5	20.3	14.47 *
TxB (error 1)	4	5.6	1.4	
Depth (D)	4	3718.8	929.7	808.44 *
DxB (error 2)	8	9.2	1.2	
DxT	8	39.9	5.0	4.57 *
DxTxB (error 3)	16	17.4	1.1	
Sampling date (D)	8	3608.7	451.1	1288.80 *
SxT	16	58.6	3.7	10.49 *
SxD	32	2484.5	77.6	221.83 *
SxTxD	64	28.3	0.4	1.26
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	240	84.7	0.3	
1983 (all depths)				
Block (B)	2	2.8	1.4	1.04
Treatment (T)	2	58.1	29.0	21.35 *
TxB (error 1)	4	5.4	1.4	
Depth (D)	4	2667.3	666.8	281.36 *
DxB (error 2)	8	19.0	2.4	
DxT	8	84.2	10.5	3.96 *
DxTxB (error 3)	16	42.5	2.7	
Sampling date (D)	12	7224.0	602.0	668.89 *
SxT	24	73.4	3.1	3.40 *
SxD	48	2850.3	59.4	65.98 *
SxTxD	96	134.1	1.4	1.56 *
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	270	243.0	0.9	
1984 (all depths)				
Block (B)	2	1.0	0.5	0.07
Treatment (T)	2	116.4	58.2	8.05
TxB (error 1)	3	21.7	7.2	
Depth (D)	4	4178.4	1044.6	555.64 *
DxB (error 2)	8	15.0	1.9	
DxT	8	126.0	15.8	2.09
DxTxB (error 3)	12	90.2	7.5	
Sampling date (D)	11	3942.6	358.4	373.35 *
SxT	22	57.3	2.6	2.71 *
SxD	44	2590.2	58.9	61.32 *
SxTxD	88	103.8	1.2	1.23
SxB + SxTxB + SxDxB + SxTxDxB (error 4)	271	260.4	1.0	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 9 Continued. ANOVA tables of soil temperatures from buried thermisters.

Source	df†	SS	MS	F
1982 5-cm depth				
Block (B)	2	3.2	1.6	2.45
Treatment (T)	2	24.8	12.4	18.79 *
BxT (error 1)	4	2.6	0.7	
Sampling date (S)	8	3392.2	424.0	1060.08 *
SxT	16	21.3	1.3	3.32 *
SxB + SxTxB (error 2)	48	19.1	0.4	
1982 15-cm depth				
Block (B)	2	3.0	1.5	1.05
Treatment (T)	2	34.2	17.1	11.94 *
BxT (error 1)	4	5.7	1.4	
Sampling date (S)	8	1773.4	221.7	651.97 *
SxT	16	26.6	1.7	4.88 *
SxB + SxTxB (error 2)	48	16.2	0.3	
1982 50-cm depth				
Block (B)	2	0.3	0.2	0.14
Treatment (T)	2	3.1	1.5	1.24
BxT (error 1)	4	5.0	1.2	
Sampling date (S)	8	572.1	71.5	340.52 *
SxT	16	10.9	0.7	3.24 *
SxB + SxTxB (error 2)	48	10.0	0.2	
1982 100-cm depth				
Block (B)	2	5.6	2.8	1.30
Treatment (T)	2	4.8	2.4	1.13
BxT (error 1)	4	8.6	2.1	
Sampling date (S)	8	213.0	26.6	42.95 *
SxT	16	16.5	1.0	1.66
SxB + SxTxB (error 2)	48	30.0	0.6	
1982 150-cm depth				
Block (B)	2	16.6	8.3	29.57 *
Treatment (T)	2	13.5	6.8	24.18 *
BxT (error 1)	4	1.1	0.3	
Sampling date (S)	8	142.5	17.8	89.10 *
SxT	16	11.6	0.7	3.60 *
SxB + SxTxB (error 2)	48	9.5	0.2	
1983 5-cm depth				
Block (B)	2	3.4	1.7	0.82
Treatment (T)	2	56.1	28.1	13.69 *
BxT (error 1)	4	8.21	2.0	
Sampling date (S)	12	3329.4	277.5	180.17 *
SxT	24	75.2	3.1	2.03 *
SxB + SxTxB (error 2)	48	73.8	1.5	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 9 Continued. ANOVA tables of soil temperatures from buried thermisters.

Source	df[†]	SS	MS	F
1983 15-cm depth				
Block (B)	2	2.8	1.4	0.44
Treatment (T)	2	64.0	32.0	10.17 *
BxT (error 1)	4	12.6	3.2	
Sampling date (S)	12	3345.6	278.8	197.73 *
SxT	24	59.1	2.5	1.74 *
SxB + SxTxB (error 2)	54	75.9	1.4	
1983 50-cm depth				
Block (B)	2	11.2	5.6	1.00
Treatment (T)	2	13.9	6.9	1.24
BxT (error 1)	4	22.4	5.6	
Sampling date (S)	12	1664.8	138.7	123.88 *
SxT	24	47.3	2.0	1.76 *
SxB + SxTxB (error 2)	56	62.9	1.1	
1983 100-cm depth				
Block (B)	2	0.4	0.2	0.33
Treatment (T)	2	2.2	1.1	1.87
BxT (error 1)	4	2.4	0.6	
Sampling date (S)	12	1021.3	85.1	340.44 *
SxT	24	13.5	0.6	2.24 *
SxB + SxTxB (error 2)	56	14.2	0.2	
1983 150-cm depth				
Block (B)	2	3.8	1.9	3.58
Treatment (T)	2	2.4	1.2	2.28
BxT (error 1)	4	2.1	0.5	
Sampling date (S)	12	581.6	48.5	167.14 *
SxT	24	11.6	0.5	1.66
SxB + SxTxB (error 2)	56	16.2	0.3	
1984 5-cm depth				
Block (B)	2	1.6	0.8	0.03
Treatment (T)	2	170.4	85.2	2.84
BxT (error 1)	3	90.2	30.0	
Sampling date (S)	11	1994.9	181.4	67.42 *
SxT	22	95.3	4.3	1.61
SxB + SxTxB (error 2)	53	142.7	2.7	
1984 15-cm depth				
Block (B)	2	2.2	1.1	0.41
Treatment (T)	2	57.2	28.6	10.59 *
BxT (error 1)	3	8.1	2.7	
Sampling date (S)	11	1881.5	171.0	159.85 *
SxT	22	22.5	1.0	0.95
SxB + SxTxB (error 2)	53	56.5	1.1	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 9 Continued. ANOVA tables of soil temperatures from buried thermisters.

Source	df†	SS	MS	F
1984 50-cm depth				
Block (B)	2	5.2	2.6	1.28
Treatment (T)	2	2.0	1.0	0.48
BxT (error 1)	3	6.1	2.0	
Sampling date (S)	11	1165.9	106.0	321.18 *
SxT	22	16.7	0.8	2.30 *
SxB + SxTxB (error 2)	55	18.1	0.3	
1984 100-cm depth				
Block (B)	2	0.5	0.3	0.11
Treatment (T)	2	5.4	2.7	1.19
BxT (error 1)	3	6.8	2.3	
Sampling date (S)	11	916.3	83.3	203.17 *
SxT	22	15.4	0.7	1.70
SxB + SxTxB (error 2)	55	22.7	0.4	
1984 150-cm depth				
Block (B)	2	6.5	3.2	17.94 *
Treatment (T)	2	5.0	2.5	13.89 *
BxT (error 1)	3	0.5	0.2	
Sampling date (S)	11	606.0	55.1	148.89 *
SxT	22	11.2	0.5	1.38
SxB + SxTxB (error 2)	55	20.4	0.4	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 10. Mean soil temperatures (°C) at five depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1982						
23 JUN	all	19.9	12.9	7.3	4.2	0.6
29 JUN	all	17.9	14.0	9.6	5.9	1.3
14 JUL	all	16.5	13.7	9.7	6.3	3.2
28 JUL	all	15.7	14.0	9.3	6.9	4.0
17 AUG	all	11.4	10.3	8.3	6.9	4.8
01 SEP	all	10.3	8.9	6.8	5.7	4.1
16 SEP	all	8.4	8.6	6.4	5.0	3.4
01 OCT	all	2.6	2.9	3.9	3.8	3.1
13 OCT	all	0.0	0.4	1.3	1.6	1.7
		INT *	INT	INT	INT	INT
all	Zero-N	12.2	10.4	7.2	5.2	2.8
all	$Ca(NO_3)_2$	11.1	9.0	6.9	5.4	3.4
all	Urea	11.0	9.1	6.7	4.8	2.4
		INT	INT	INT	INT	INT
23 JUN	Zero-N	19.9 j	12.9 gh	6.6 cd	3.4 bc	-0.1 a
23 JUN	$Ca(NO_3)_2$	19.9 j	12.9 gh	7.8 ef	5.4 defghi	1.7 b
23 JUN	Urea	19.9 j	12.9 gh	7.4 def	4.0 cd	0.1 a
29 JUN	Zero-N	18.1 i	14.7 ij	9.2 hi	5.0 cfefg	0.4 a
29 JUN	$Ca(NO_3)_2$	18.1 i	13.8 hi	10.1 jk	7.2 ijk	2.7 de
29 JUN	Urea	17.4 i	13.4 gh	9.6 hijk	5.5 defghij	0.6 a
14 JUL	Zero-N	18.5 i	15.4 jk	10.1 jk	6.7 ghijk	2.9 def
14 JUL	$Ca(NO_3)_2$	15.5 h	12.9 gh	9.7 ijk	5.9 efghijk	4.1 gh
14 JUL	Urea	15.4 h	12.8 g	9.3 hij	6.3 fghijk	2.5 cd
28 JUL	Zero-N	17.5 i	16.3 k	10.2 k	7.3 jk	4.1 gh
28 JUL	$Ca(NO_3)_2$	14.9 h	12.7 g	8.9 h	7.1 hijk	4.4 hi
28 JUL	Urea	14.9 h	13.0 gh	8.8 gh	6.3 fghijk	3.3 ef
17 AUG	Zero-N	12.5 g	11.7 f	9.1 hi	7.5 k	5.1 i
17 AUG	$Ca(NO_3)_2$	10.8 def	9.5 d	8.0 fg	6.8 ghijk	4.8 hi
17 AUG	Urea	10.9 ef	9.6 de	7.9 f	6.4 fghijk	4.3 gh
01 SEP	Zero-N	11.4 fg	10.6 e	7.5 ef	6.3 fghijk	4.4 hi
01 SEP	$Ca(NO_3)_2$	9.7 de	8.0 c	6.5 cd	5.7 defghijk	4.2 gh
01 SEP	Urea	9.9 de	8.2 c	6.3 cd	5.3 defgh	3.6 fg
16 SEP	Zero-N	8.4 c	8.9 cd	7.0 de	5.3 defgh	3.6 fg
16 SEP	$Ca(NO_3)_2$	8.5 c	8.4 c	6.1 c	5.0 cdefg	3.6 fg
16 SEP	Urea	8.4 c	8.5 c	6.2 c	4.6 cdef	3.1 def
01 OCT	Zero-N	2.9 b	2.9 b	3.9 b	3.8 cd	3.2 def
01 OCT	$Ca(NO_3)_2$	2.5 b	2.9 b	4.0 b	4.1 cde	3.3 ef
01 OCT	Urea	2.3 b	2.8 b	3.7 b	3.6 c	2.8 de
13 OCT	Zero-N	0.5 a	0.6 a	1.3 a	1.6 ab	1.8 bc
13 OCT	$Ca(NO_3)_2$	-0.2 a	0.3 a	1.3 a	1.7 ab	1.9 bc
13 OCT	Urea	-0.4 a	0.3 a	1.3 a	1.5 a	1.6 b
	BLSD	1.12	0.96	0.81	1.85	0.77

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 10 Continued. Mean soil temperatures (°C) at five depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1983						
26 APR	all	5.4	2.2	-0.2	-0.5	-0.6
04 MAY	all	3.3	2.3	0.7	0.3	0.1
11 MAY	all	11.6	7.6	0.7	-0.2	-0.5
01 JUN	all	20.2	16.9	7.0	3.3	0.0
14 JUN	all	17.1	16.0	7.9	4.5	1.1
28 JUN	all	17.4	16.9	11.4	8.3	3.9
13 JUL	all	16.5	14.8	10.8	8.6	5.5
27 JUL	all	17.4	16.2	11.1	8.8	5.9
10 AUG	all	12.9	13.5	10.6	8.9	6.4
23 AUG	all	11.2	10.1	8.7	7.5	5.6
07 SEP	all	5.8	5.3	5.6	5.4	4.8
22 SEP	all	5.8	5.9	5.0	4.4	3.6
05 OCT	all	0.3	0.6	1.6	2.0	2.0
		INT *	INT	INT	INT	INT
all	Zero-N	12.6	11.3	6.4	5.2	3.2
all	$Ca(NO_3)_2$	10.2	9.4	6.1	5.1	3.3
all	Urea	9.5	8.9	6.7	4.1	2.3
		INT	INT	INT	INT	INT
26 APR	Zero-N	9.5 f	5.5 c	-0.0 a	-0.5 a	-0.6 a
26 APR	$Ca(NO_3)_2$	4.3 cde	0.8 a	-0.3 a	-0.5 a	-0.7 a
26 APR	Urea	2.4 abc	0.2 a	-0.2 a	-0.4 a	-0.5 ab
04 MAY	Zero-N	4.4 cde	3.8 bc	0.6 a	0.3 a	0.1 ab
04 MAY	$Ca(NO_3)_2$	2.8 abcd	1.8 ab	0.8 a	0.3 a	0.0 ab
04 MAY	Urea	2.8 bcd	1.8 ab	0.6 a	0.2 a	0.1 ab
11 MAY	Zero-N	12.1 fghi	11.5 defg	0.2 a	-0.2 a	-0.4 ab
11 MAY	$Ca(NO_3)_2$	12.7 ghij	5.8 c	0.1 a	-0.3 a	-0.5 ab
11 MAY	Urea	10.1 fg	5.6 c	1.8 a	-0.2 a	-0.5 ab
01 JUN	Zero-N	20.8 qr	17.0 klm	5.8 bcd	2.9 b	-0.1 ab
01 JUN	$Ca(NO_3)_2$	21.1 r	16.4 jklm	6.3 bcde	4.0 c	0.4 ab
01 JUN	Urea	18.3 opq	17.4 klm	10.0 ghijk	2.8 b	-0.2 ab
14 JUN	Zero-N	17.6 nop	16.3 jklm	6.6 bcde	4.0 cd	0.7 b
14 JUN	$Ca(NO_3)_2$	17.5 nop	15.4 ijk	7.4 cdef	5.3 ef	2.1 cd
14 JUN	Urea	16.2 lmno	16.2 jklm	10.6 hijkl	3.9 c	0.2 ab
28 JUN	Zero-N	19.0 pqr	18.1 lm	11.1 hijkl	8.0 hi	3.5 ef
28 JUN	$Ca(NO_3)_2$	16.2 lmno	16.0 jklm	10.7 hijkl	9.2 klm	4.6 fghij
28 JUN	Urea	16.8 mnop	16.3 jklm	13.1 l	7.4 gh	3.2 de
13 JUL	Zero-N	18.1 nop	15.9 ijklm	10.8 hijkl	9.1 jklm	5.8 jklmn
13 JUL	$Ca(NO_3)_2$	15.9 lmno	14.0 ghij	10.2 ghijk	8.5 ijkl	5.8 jklmn
13 JUL	Urea	14.8 jklm	14.2 hij	11.8 jkl	8.0 hi	4.6 fghij
27 JUL	Zero-N	19.1 pqr	18.2 m	11.4 ijkl	9.5 lm	6.4 mn
27 JUL	$Ca(NO_3)_2$	16.6lmnop	14.7 hijk	10.0 ghijk	8.6 ijklm	6.0 klmn
27 JUL	Urea	15.6 klmn	15.4 ijkl	12.2 kl	7.9 hi	4.8 ghijk
10 AUG	Zero-N	14.1 ijkl	14.8 hijk	10.9 hijkl	9.5 m	7.0 n
10 AUG	$Ca(NO_3)_2$	11.6 fghi	12.3 efgh	9.7 fghij	8.8 ijklm	6.5 mn
10 AUG	Urea	13.2 ijk	13.2 fghi	11.6 ijkl	8.2 hijk	5.4 ijklm

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 10 Continued. Mean soil temperatures (°C) at five depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1983						
23 AUG	Zero-N	12.8 hij *	11.1 def	9.3 fghi	8.1 hij	6.1 lmn
23 AUG	$Ca(NO_3)_2$	10.2 fgh	9.3 d	8.1 defg	7.3 gh	5.7 ijklm
23 AUG	Urea	9.8 f	9.8 de	8.6 efgh	6.8 g	4.8 fghijk
07 SEP	Zero-N	6.6 e	5.4 c	6.0 bcd	5.8 f	5.0 hijkl
07 SEP	$Ca(NO_3)_2$	5.2 de	5.0 c	5.5 bc	5.4 ef	4.8 fghijk
07 SEP	Urea	5.3 de	5.6 c	5.3 bc	5.0 def	4.4 efghi
22 SEP	Zero-N	6.3 e	6.1 c	5.1 bc	4.6 cde	4.0 efgh
22 SEP	$Ca(NO_3)_2$	5.6 e	5.7 c	4.7 b	4.3 cd	3.6 efg
22 SEP	Urea	5.6 e	5.8 c	5.1 bc	4.1 cd	3.2 de
05 OCT	Zero-N	0.3 ab	0.6 a	1.9 a	2.2 b	2.2 cd
05 OCT	$Ca(NO_3)_2$	0.2 a	0.7 a	1.6 a	1.9 b	2.0 cd
05 OCT	Urea	0.4 ab	0.6 a	1.2 a	1.8 b	1.8 c
	BLSD	2.6	2.7	2.4	1.0	1.3
1984						
11 MAY	all	5.9	4.1	0.2	-0.2	-0.5
16 MAY	all	10.3	7.2	0.1	-0.5	-0.7
07 JUN	all	18.5	17.2	5.6	2.5	-0.2
13 JUN	all	15.7	14.3	7.0	4.2	0.4
28 JUN	all	17.5	15.9	9.8	7.0	2.6
12 JUL	all	13.9	13.2	9.3	7.3	4.3
25 JUL	all	14.4	14.3	10.6	8.6	5.5
08 AUG	all	12.1	12.2	11.1	9.4	6.5
22 AUG	all	10.6	9.8	9.6	8.4	6.3
05 SEP	all	6.9	6.6	6.2	5.7	4.9
18 SEP	all	3.5	3.9	5.9	5.4	4.3
02 OCT	all	5.5	4.9	4.0	3.6	2.9
		INT	**INT**	**INT**	**INT**	**INT**
all	Zero-N	12.8	11.3	6.7	5.2	3.2
all	$Ca(NO_3)_2$	11.0	10.1	6.4	5.3	3.2
all	Urea	9.4	9.4	6.8	4.7	2.5
	BLSD	**INT**	**INT**	**INT**	**INT**	**INT**
11 MAY	Zero-N	8.0 bcde	4.8 abc	0.0 a	-0.2 a	-0.4 abc
11 MAY	$Ca(NO_3)_2$	5.6 abcd	3.6 a	0.0 a	-0.3 a	-0.5 ab
11 MAY	Urea	3.2 a	3.6 ab	0.8 ab	-0.2 a	-0.4 ab
16 MAY	Zero-N	14.1 ijklm	8.7 def	-0.3 a	-0.5 a	-0.7 a
16 MAY	$Ca(NO_3)_2$	9.4 defgh	6.7 bcde	-0.3 a	-0.4 a	-0.8 a
16 MAY	Urea	5.5 abc	5.6 abcd	1.4 b	-0.6 a	-0.8 a
07 JUN	Zero-N	20.6 o	18.4 m	5.1 cd	2.0 bc	-0.4 abc
07 JUN	$Ca(NO_3)_2$	19.0 no	17.1 lm	5.8 def	3.4 cd	0.1 abc
07 JUN	Urea	14.5 ijklm	15.4 klm	6.0 def	1.8 b	-0.4 abc
13 JUN	Zero-N	17.0 lmno	15.1 jkl	6.4 efg	3.4 cd	-0.1 abc
13 JUN	$Ca(NO_3)_2$	15.9 jklmn	14.0 ijkl	7.3 gh	5.1 efg	1.1 bcd
13 JUN	Urea	13.2 ghijkl	13.4 ijk	7.6 h	3.8 def	-0.1 abc

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 10 Continued. Mean soil temperatures (°C) at five depths.

Sample Date	Fertilizer Treatment	5-cm	15-cm	50-cm	100-cm	150-cm
1984						
28 JUN	Zero-N	18.8 no *	16.4 klm	9.4 ijk	6.6 ghij	2.3 de
28 JUN	$Ca(NO_3)_2$	17.7 mno	15.9 klm	10.1 jkl	8.0 jkl	3.8 efghi
28 JUN	Urea	15.2 ijklmn	15.2 klm	10.0 jkl	6.2 ghi	1.2 cd
12 JUL	Zero-N	16.1 klmn	15.2 jkl	9.7 ijk	7.7 ijkl	4.5 fghijk
12 JUL	$Ca(NO_3)_2$	12.9 fghijk	12.1 hij	8.8 i	7.4 ijk	4.6 ghijk
12 JUL	Urea	12.1 fghij	11.9 ghi	9.3 ij	6.7 hij	3.5 efgh
25 JUL	Zero-N	15.2 ijklmn	15.5 klm	11.3 mn	9.1 lm	6.0 klmno
25 JUL	$Ca(NO_3)_2$	13.9 ijklm	13.6 ijk	10.0 ijk	8.4 kl	5.6 jklmno
25 JUL	Urea	13.8 ijklm	13.6 ijk	10.6 klm	8.0 jkl	4.8 hijklm
08 AUG	Zero-N	13.3 hijkl	13.8 ijk	11.7 n	9.9 m	7.0 o
08 AUG	$Ca(NO_3)_2$	11.5 efghi	11.4 fghi	10.5 klm	9.1 lm	6.4 mno
08 AUG	Urea	11.4 efghi	11.2 fghi	11.2 lmn	9.0 lm	5.8 jklmno
22 AUG	Zero-N	12.8 fghijk	11.3 fghi	10.2jklm	9.0 lm	6.8 no
22 AUG	$Ca(NO_3)_2$	9.3 cdefg	9.0 efgh	9.1 ij	8.2 kl	6.3 lmno
22 AUG	Urea	9.2 cdef	8.9 efg	9.2 ij	7.8 jkl	5.5 jklmno
05 SEP	Zero-N	7.8 bcde	7.1 cde	6.7 fgh	6.2 ghi	5.3 ijklmn
05 SEP	$Ca(NO_3)_2$	6.5 abcd	6.3 abcde	6.0 def	5.5 gh	4.8 hijkl
05 SEP	Urea	6.0 abcd	6.2 abcde	6.0 def	5.2 fgh	4.4 fghij
18 SEP	Zero-N	3.1 a	3.8 ab	6.2defg	5.6 gh	4.5 fghijk
18 SEP	$Ca(NO_3)_2$	3.4 a	4.0 abc	5.6 de	5.4 gh	4.4 fghijk
18 SEP	Urea	4.2 ab	4.0 abc	5.9 def	5.2 efg	3.8 efghi
02 OCT	Zero-N	6.9 abcd	5.5 abc	4.1 c	3.7 de	3.1 efg
02 OCT	$Ca(NO_3)_2$	4.9 ab	4.6 abc	4.0 c	3.6 d	3.0 ef
02 OCT	Urea	4.4 ab	4.3 abc	4.0 c	3.4 cd	2.6 de
	BLSD	3.94	3.14	1.15	1.50	1.59

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD).

Table 11. ANOVA tables of ammonia-N volatilization losses.

Source	df	SS	MS	F
All years				
Block (B)	4	331	83	2.83
Treatment (T)	2	132	66	2.25
TxB (error 1)	8	234	29	
Sampling (S)	1	500	500	6.36 *
SxT	2	303	151	2.45
SxB + SxTxB (error 2)	12	810	67	
Year (Y)	2	187	94	1.66
YxT	4	18	4	0.08
YxS	2	928	464	8.25 *
YxTxS	4	367	92	1.63
YxB + YxTxB + YxSxB + YxTxSxB (error 3)	48	2700	56	
1982				
Block (B)	4	101	25	0.50
Treatment (T)	2	61	30	0.60
TxB (error 1)	8	404	50	
Sampling (S)	1	2	2	0.02
SxT	2	536	268	2.43
SxB + SxTxB (error 2)	12	1326	111	
1983				
Block (B)	4	528	132	9.67 *
Treatment (T)	2	13	6	0.46
TxB (error 1)	8	109	14	
Sampling (S)	1	1420	1420	24.95 *
SxT	2	26	13	0.23
SxB + SxTxB (error 2)	12	683	57	
1984				
Block (B)	4	590	148	20.19 *
Treatment (T)	2	76	38	5.20 *
TxB (error 1)	8	58	7	
Sampling (S)	1	7	7	0.29
SxT	2	107	54	2.34
SxB + SxTxB (error 2)	12	275	23	

* Significant at the 5% level of probability.

Table 12. Mean separations of ammonia-N volatilization losses.

Year	Fertilizer Treatment	Sampling Set	NH_3-N loss (g/ha/day)
1982	Zero-N	all	6.0
	Urea (Inc.)	all	7.4
	Urea (Surf.)	all	9.5
			NS *
	all	First	7.4
	all	Second	7.9
			NS
1983	Zero-N	all	10.2
	Urea (Inc.)	all	11.2
	Urea (Surf.)	all	11.7
			NS
	all	First	17.9 b
	all	Second	4.2 a
1984	Zero-N	all	6.5 a
	Urea (Inc.)	all	8.9 ab
	Urea (Surf.)	all	10.3 b
	all	First	9.0 b
	all	Second	8.1 a

* Means followed by the same letter in a column are not significantly different at the 5% level of probability by Waller and Duncan's Least Significant Difference test (BLSD). NS indicates not significant.

Table 13. ANOVA tables of nitrate-N in soil water samples from lysimeters.

Source	df†	SS	MS	F
1982 75-cm depth				
Block (B)	4	19	5	0.21
Treatment (T)	2	71	36	1.58
BxT (error 1)	6	135	23	
Date (D)	8	478	60	4.85 *
DxT	8	303	38	3.07 *
DxB + DxTxB (error 2)	23	283	12	
1982 150-cm depth				
Block (B)	4	237	59	0.67
Treatment (T)	2	92	46	0.52
BxT (error 1)	7	620	89	
Date (D)	7	420	60	3.42 *
DxT	13	99	8	0.43
DxB + DxTxB (error 2)	38	667	18	
1983 75-cm depth				
Block (B)	4	1888	472	0.88
Treatment (T)	2	1696	848	1.58
BxT (error 1)	8	4290	536	
Date (D)	9	401	45	2.52 *
DxT	18	180	10	0.57
DxB + DxTxB (error 2)	55	971	18	
1983 150-cm depth				
Block (B)	4	656	164	0.62
Treatment (T)	2	643	321	1.22
BxT (error 1)	8	2102	263	
Date (D)	8	285	36	3.21 *
DxT	13	206	16	1.43
DxB + DxTxB (error 2)	36	399	11	
1984 75-cm depth				
Block (B)	4	107	27	1.61
Treatment (T)	2	75	37	2.25
BxT (error 1)	3	50	17	
Date (D)	3	48	16	3.50
DxT	5	18	4	0.79
DxB + DxTxB (error 2)	7	32	5	
1984 150-cm depth				
Block (B)	4	1557	389	0.64
Treatment (T)	2	825	412	0.68
BxT (error 1)	3	1830	610	
Date (D)	5	769	154	2.18
DxT	7	1974	282	4.00 *
DxB + DxTxB (error 2)	10	705	70	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 14. Mean separations of nitrate-N in soil water samples from lysimeters.

Sampling Date	Fertilizer Treatment	75-cm Depth (µg N/mL)	150-cm depth (µg N/mL)
1982			
19 MAY 82	all	3.5	
15 JUN 82	all	6.0	6.5 ab *
29 JUN 82	all	11.1	4.3 a
14 JUL 82	all	7.3	4.0 a
28 JUL 82	all	5.2	4.2 a
17 AUG 82	all	4.0	6.0 ab
01 SEP 82	all	2.3	10.3 b
16 SEP 82	all	2.0	10.9 b
01 OCT 82	all	0.5	10.2 b
	BLSD	INT	5.7
all	Zero-N	4.1	3.8
all	$Ca(NO_3)_2$	11.5	7.7
all	Urea	6.9	8.8
		INT	NS
19 MAY 82	Zero-N	2.5 ab	
19 MAY 82	$Ca(NO_3)_2$		
19 MAY 82	Urea	4.2 ab	
15 JUN 82	Zero-N	6.7 ab	4.9
15 JUN 82	$Ca(NO_3)_2$	6.1 ab	8.6
15 JUN 82	Urea	4.9 ab	
29 JUN 82	Zero-N	5.9 ab	0.3
29 JUN 82	$Ca(NO_3)_2$	25.1 c	6.6
29 JUN 82	Urea	10.6 b	5.3
14 JUL 82	Zero-N	5.6 ab	1.1
14 JUL 82	$Ca(NO_3)_2$		5.7
14 JUL 82	Urea	8.6 ab	4.7
28 JUL 82	Zero-N	3.5 ab	2.7
28 JUL 82	$Ca(NO_3)_2$	10.7 b	6.2
28 JUL 82	Urea	5.0 ab	4.8
17 AUG 82	Zero-N	3.3 ab	2.8
17 AUG 82	$Ca(NO_3)_2$		3.1
17 AUG 82	Urea	5.3 ab	9.8
01 SEP 82	Zero-N	2.3 ab	9.5
01 SEP 82	$Ca(NO_3)_2$		10.4
01 SEP 82	Urea		11.0
16 SEP 82	Zero-N	2.2 ab	5.1
16 SEP 82	$Ca(NO_3)_2$	1.7 ab	13.4
16 SEP 82	Urea		12.5
01 OCT 82	Zero-N	0.5 a	0.3
01 OCT 82	$Ca(NO_3)_2$		8.8
01 OCT 82	Urea		13.4
	BLSD	9.3	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 14 Continued. Mean separations of nitrate-N in soil water samples from lysimeters.

Sampling Date	Fertilizer Treatment	75-cm Depth (μg N/mL)	150-cm depth (μg N/mL)
1983			
09 MAY 83	all	7.9 cd *	
15 JUN 83	all	9.2 d	11.9 b
28 JUN 83	all	10.4 d	12.4 b
13 JUL 83	all	9.2 d	13.1 bc
27 JUL 83	all	6.3 bcd	13.3 bc
10 AUG 83	all	4.6 abcd	15.3 cd
23 AUG 83	all	1.9 ab	16.3 d
07 SEP 83	all	0.4 a	9.0 a
22 SEP 83	all	3.0 abc	9.4 a
06 OCT 83	all	1.2 ab	16.8 d
	BLSD	5.8	2.2
all	Zero-N	3.0	7.1
all	$Ca(NO_3)_2$	12.1	15.6
all	Urea	4.4	15.9
		NS	NS
09 MAY 83	Zero-N	5.6	
09 MAY 83	$Ca(NO_3)_2$	20.3	
09 MAY 83	Urea	6.9	
15 JUN 83	Zero-N	6.0	5.9
15 JUN 83	$Ca(NO_3)_2$	14.3	19.5
15 JUN 83	Urea	5.9	15.3
28 JUN 83	Zero-N	7.8	9.3
28 JUN 83	$Ca(NO_3)_2$	20.4	12.8
28 JUN 83	Urea	4.9	16.2
13 JUL 83	Zero-N	4.8	7.8
13 JUL 83	$Ca(NO_3)_2$	18.2	14.6
13 JUL 83	Urea	4.6	15.6
27 JUL 83	Zero-N	3.6	8.5
27 JUL 83	$Ca(NO_3)_2$	12.5	15.5
27 JUL 83	Urea	4.3	15.3
10 AUG 83	Zero-N	1.1	7.9
10 AUG 83	$Ca(NO_3)_2$	7.8	19.9
10 AUG 83	Urea	5.5	20.6
23 AUG 83	Zero-N	0.6	10.8
23 AUG 83	$Ca(NO_3)_2$	5.0	
23 AUG 83	Urea	2.6	18.1
07 SEP 83	Zero-N	0.2	3.8
07 SEP 83	$Ca(NO_3)_2$	1.4	16.7
07 SEP 83	Urea	0.2	11.9
22 SEP 83	Zero-N	0.4	6.2
22 SEP 83	$Ca(NO_3)_2$	7.3	8.1
22 SEP 83	Urea	0.7	12.4

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 14 Continued. Mean separations of nitrate-N in soil water samples from lysimeters.

Sampling Date	Fertilizer Treatment	75-cm Depth (μg N/mL)	150-cm depth (μg N/mL)
1983			
06 OCT 83	Zero-N	0.6	
06 OCT 83	$Ca(NO_3)_2$	3.6	
06 OCT 83	Urea		16.8
		NS *	NS
1984			
31 MAY 84	all	4.5	15.9
28 JUN 84	all	7.6	15.6
08 AUG 84	all		17.6
05 SEP 84	all	2.3	16.6
18 SEP 84	all		7.7
04 OCT 84	all	5.1	25.8
		NS	INT
all	Zero-N	3.1	6.9
all	$Ca(NO_3)_2$	7.6	24.4
all	Urea	4.2	26.4
		NS	INT
31 MAY 84	Zero-N	4.3	
31 MAY 84	$Ca(NO_3)_2$		
31 MAY 84	Urea	4.8	15.9 abc
28 JUN 84	Zero-N	7.2	3.1 a
28 JUN 84	$Ca(NO_3)_2$	8.8	21.0 abc
28 JUN 84	Urea	6.3	20.0 abc
08 AUG 84	Zero-N		23.0 abcd
08 AUG 84	$Ca(NO_3)_2$		29.8 bcd
08 AUG 84	Urea		0.0 a
05 SEP 84	Zero-N	0.5	5.9 ab
05 SEP 84	$Ca(NO_3)_2$	5.4	24.1 abcd
05 SEP 84	Urea	0.2	23.4 abcd
18 SEP 84	Zero-N		3.9 a
18 SEP 84	$Ca(NO_3)_2$		11.5 abc
18 SEP 84	Urea		
04 OCT 84	Zero-N	1.4	6.7 ab
04 OCT 84	$Ca(NO_3)_2$	8.5	33.6 cd
04 OCT 84	Urea	3.7	46.0 d
	BLSD	NS	24.6

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 15. ANOVA tables of plant weight and nitrogen uptake from main plots.

Source	df†	SS	MS	F
Plant N concentration (µg/g)				
14 JUL 82				
Block (B)	4	88446617	22111654	3.06 *
Fertilizer Source (F)	2	688026617	344013308	47.57 *
Placement (P)	1	2458892	2458892	0.34
FxP	2	138010	69005	0.01
BxF + BxP + BxFxP (error)	20	144619386	7230969	
28 JUL 82				
Block (B)	4	6544630	1636157	0.45
Fertilizer Source (F)	2	297403615	148701807	41.30 *
Placement (P)	1	2288040	2288040	0.64
FxP	2	508304	254152	0.07
BxF + BxP + BxFxP (error)	17	61210400	3600612	
17 AUG 82				
Block (B)	4	7133558	1783389	2.40
Fertilizer Source (F)	2	111102035	55551017	74.66 *
Placement (P)	1	6965554	6965554	9.36 *
FxP	2	7198146	3599073	4.84
BxF + BxP + BxFxP (error)	17	12649028	744060	
13 JUL 83				
Block (B)	4	46820333	11705083	2.13
Fertilizer Source (F)	2	705265664	352632832	64.10 *
Placement (P)	1	16320313	16320313	2.97
FxP	2	19024069	9512034	1.73
BxF + BxP + BxFxP (error)	19	104530128	5501586	
27 JUL 83				
Block (B)	4	4242847	1060712	0.23
Fertilizer Source (F)	2	508932976	254466488	55.08 *
Placement (P)	1	33663495	33663495	7.29 *
FxP	2	35826815	17913408	3.88 *
BxF + BxP + BxFxP (error)	20	92402806	4620140	
10 AUG 83				
Block (B)	4	5229391	1307348	0.33
Fertilizer Source (F)	2	129994112	64997056	16.20 *
Placement (P)	1	2301870	2301870	0.57
FxP	2	9752023	4876012	1.22
BxF + BxP + BxFxP (error)	20	80245677	4012284	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 15 Continued. ANOVA tables of plant weight and nitrogen uptake from main plots.

Source	df†	SS	MS	F
Plant N concentration (µg/g)				
28 JUN 84				
Block (B)	4	16284838	4071210	0.33
Fertilizer Source (F)	2	1825219443	912609721	74.75 *
Placement (P)	1	32178163	32178163	2.64
FxP	2	91028003	45514002	3.73 *
BxF + BxP + BxFxP (error)	20	244172606	12208630	
25 JUL 84				
Block (B)	4	10761412	2690353	1.03
Fertilizer Source (F)	2	232193852	116096926	44.51 *
Placement (P)	1	2976554	2976554	1.14
FxP	2	4367267	2183633	0.84
BxF + BxP + BxFxP (error)	19	49562527	2608554	
08 AUG 84				
Block (B)	4	1646962	411741	0.27
Fertilizer Source (F)	2	131801613	65900807	43.27 *
Placement (P)	1	3487705	3487705	2.29
FxP	2	1754743	877372	0.58
BxF + BxP + BxFxP (error)	18	27413100	1522950	
Plant matter dry weight (kg/ha).				
14 JUL 82				
Block (B)	4	3002340	750585	2.71
Fertilizer Source (F)	2	8750561	4375281	15.78 *
Placement (P)	1	293024	293024	1.06
FxP	2	377646	188823	0.68
BxF + BxP + BxFxP (error)	20	5544509	277225	
28 JUL 82				
Block (B)	4	3323886	830972	0.89
Fertilizer Source (F)	2	31216394	15608197	16.66 *
Placement (P)	1	18130	18130	0.02
FxP	2	1428549	714275	0.76
BxF + BxP + BxFxP (error)	20	18733734	936687	
17 AUG 82				
Block (B)	4	21217073	5304268	1.46
Fertilizer Source (F)	2	97840363	48920181	13.47 *
Placement (P)	1	8254119	8254119	2.27
FxP	2	6045633	3022817	0.83
BxF + BxP + BxFxP (error)	20	72609442	3630472	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 15 Continued. ANOVA tables of plant weight and nitrogen uptake from main plots.

Source	df†	SS	MS	F
Plant matter dry weight (kg/ha).				
13 JUL 83				
Block (B)	4	780454	195114	0.23
Fertilizer Source (F)	2	26219698	13109849	15.45 *
Placement (P)	1	2687804	2687804	3.17
FxP	2	3009351	1504676	1.77
BxF + BxP + BxFxP (error)	20	16972094	848605	
27 JUL 83				
Block (B)	4	10467205	2616801	3.76 *
Fertilizer Source (F)	2	73547426	36773713	52.78 *
Placement (P)	1	4308192	4308192	6.18 *
FxP	2	2277820	1138910	1.63
BxF + BxP + BxFxP (error)	20	13935898	696795	
10 AUG 83				
Block (B)	4	13575718	3393930	2.19
Fertilizer Source (F)	2	221176698	110588349	71.37 *
Placement (P)	1	6083787	6083787	3.93
FxP	2	2359222	1179611	0.76
BxF + BxP + BxFxP (error)	20	30991461	1549573	
28 JUN 84				
Block (B)	4	94877	23719	0.58
Fertilizer Source (F)	2	2395024	1197512	29.14 *
Placement (P)	1	5736	5736	0.14
FxP	2	73951	36975	0.90
BxF + BxP + BxFxP (error)	20	821764	41088	
25 JUL 84				
Block (B)	4	9721770	2430442	2.86
Fertilizer Source (F)	2	46064757	23032379	27.06 *
Placement (P)	1	185644	185644	0.22
FxP	2	1434875	717438	0.84
BxF + BxP + BxFxP (error)	20	17023085	851154	
08 AUG 84				
Block (B)	4	7290726	1822682	1.56
Fertilizer Source (F)	2	120303787	60151893	51.32 *
Placement (P)	1	1627580	1627580	1.39
FxP	2	645475	322737	0.28
BxF + BxP + BxFxP (error)	20	23441167	1172058	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 15 Continued. ANOVA tables of plant weight and nitrogen uptake from main plots.

Source	df†	SS	MS	F
Plant nitrogen uptake (kg/ha).				
14 JUL 82				
Block (B)	4	991	248	2.06
Fertilizer Source (F)	2	8800	4400	36.61 *
Placement (P)	1	79	79	0.66
FxP	2	115	57	0.48
BxF + BxP + BxFxP (error)	20	2404	120	
28 JUL 82				
Block (B)	4	104	26	0.18
Fertilizer Source (F)	2	16819	8410	58.99 *
Placement (P)	1	52	52	0.36
FxP	2	17	9	0.06
BxF + BxP + BxFxP (error)	16	2281	143	
17 AUG 82				
Block (B)	4	2782	695	1.46
Fertilizer Source (F)	2	25806	12903	27.06 *
Placement (P)	1	2	2	0.00
FxP	2	1673	837	1.75
BxF + BxP + BxFxP (error)	17	8107	477	
13 JUL 83				
Block (B)	4	555	139	1.50
Fertilizer Source (F)	2	15024	7512	80.93 *
Placement (P)	1	994	994	10.71 *
FxP	2	776	388	4.18 *
BxF + BxP + BxFxP (error)	16	1485	93	
27 JUL 83				
Block (B)	4	1403	351	2.49
Fertilizer Source (F)	2	30279	15139	107.36 *
Placement (P)	1	107	107	0.76
FxP	2	424	212	1.50
BxF + BxP + BxFxP (error)	19	2679	141	
10 AUG 83				
Block (B)	4	1150	287	1.58
Fertilizer Source (F)	2	35646	17823	97.96 *
Placement (P)	1	176	176	0.97
FxP	2	293	147	0.81
BxF + BxP + BxFxP (error)	20	3639	182	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 15 Continued. ANOVA tables of plant weight and nitrogen uptake from main plots.

Source	df†	SS	MS	F
Plant nitrogen uptake (kg/ha).				
28 JUN 84				
Block (B)	4	81	20	0.50
Fertilizer Source (F)	2	5101	2551	63.74 *
Placement (P)	1	4	4	0.11
FxP	2	24	12	0.30
BxF + BxP + BxFxP (error)	20	800	40	
25 JUL 84				
Block (B)	4	1877	469	3.11 *
Fertilizer Source (F)	2	11959	5979	39.60 *
Placement (P)	1	128	128	0.85
FxP	2	194	97	0.64
BxF + BxP + BxFxP (error)	18	2718	151	
08 AUG 84				
Block (B)	4	1254	314	1.36
Fertilizer Source (F)	2	24306	12153	52.58 *
Placement (P)	1	516	516	2.23
FxP	2	123	62	0.27
BxF + BxP + BxFxP (error)	18	4161	231	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 16. Mean separations of plant weight and nitrogen uptake from main plots.

Sampling Date	Fertilizer Treatment	Plant N (µg/g)	Plant Dry Wt. (kg/ha)	N Uptake (kg/ha)
14 Jul 82				
Fertilizer	Zero-N	16687.4 a *	1754.2 a	21.5 a
	$Ca(NO_3)_2$	27178.8 b	2688.6 b	54.4 b
	Urea	26215.8 b	2962.0 b	58.7 b
	BLSD	2236.8	458.2	9.1
Placement	Incorporated	22993.7	2347.7	42.7
	Surface	23727.6	2588.8	47.0
		NS	NS	NS
Interaction	Zero-N (Inc.)	16084.0	1501.6	17.9
	Zero-N (Surf.)	17290.8	2006.8	25.2
	$Ca(NO_3)_2$ (Inc.)	26881.4	2520.2	50.7
	$Ca(NO_3)_2$ (Surf.)	27476.2	2857.0	58.2
	Urea (Inc.)	26015.8	3021.4	59.6
	Urea (Surf.)	26415.8	2902.6	57.7
		NS	NS	NS
28 Jul 82				
Fertilizer	Zero-N	7396.1 a	3639.5 a	26.5 a
	$Ca(NO_3)_2$	15560.7 c	6057.5 b	89.8 c
	Urea	13239.3 b	5393.8 b	68.8 b
	BLSD	1690.6	840.1	10.7
Placement	Incorporated	12082.2	5054.8	60.2
	Surface	12633.0	5005.7	65.4
		NS	NS	NS
Interaction	Zero-N (Inc.)	7024.2	3355.6	24.3
	Zero-N (Surf.)	7768.0	3923.4	28.7
	$Ca(NO_3)_2$ (Inc.)	15421.2	6229.9	88.3
	$Ca(NO_3)_2$ (Surf.)	15700.2	5885.1	91.0
	Urea (Inc.)	12966.2	5579.1	68.1
	Urea (Surf.)	13457.8	5208.5	69.3
		NS	NS	NS
17 Aug 82				
Fertilizer	Zero-N	6051.4	5931.2 a	35.8 a
	$Ca(NO_3)_2$	10652.6	9427.8 b	102.8 b
	Urea	9849.6	10026.1 b	97.5 b
	BLSD	INT	1670.1	19.5
Placement	Incorporated	8264.4	8986.2	77.3
	Surface	9483.1	7937.2	80.2
		INT	NS	NS
Interaction	Zero-N (Inc.)	6137.0 a	6340.5	39.4
	Zero-N (Surf.)	5944.5 a	5521.9	31.3
	$Ca(NO_3)_2$ (Inc.)	9622.6 b	9469.3	93.3
	$Ca(NO_3)_2$ (Surf.)	11940.0 c	9386.3	114.8
	Urea (Inc.)	9226.0 b	11148.9	104.8
	Urea (Surf.)	10348.4 b	8903.3	91.7
	BLSD	1178.4	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 16 Continued. Mean separations of plant weight and nitrogen uptake from main plots.

Sampling Date	Fertilizer Treatment	Plant N (µg/g)	Plant Dry Wt. (kg/ha)	N Uptake (kg/ha)
13 Jul 83				
Fertilizer	Zero-N	10939.9 a *	711.3 a	6.7
	$Ca(NO_3)_2$	22521.4 c	2300.5 b	61.8
	Urea	19167.6 b	2933.7 b	53.7
	BLSD	1961.6	802.3	INT
Placement	Incorporated	16634.0	2281.2	44.2
	Surface	18283.0	1682.5	35.6
		NS	NS	INT
Interaction	Zero-N (Inc.)	11299.6	578.1	6.3 a
	Zero-N (Surf.)	10580.2	844.4	7.1 a
	$Ca(NO_3)_2$ (Inc.)	21039.6	2715.0	70.2 d
	$Ca(NO_3)_2$ (Surf.)	24003.2	1886.0	53.3 bc
	Urea (Inc.)	17795.0	3550.3	65.6 cd
	Urea (Surf.)	20265.6	2317.2	44.1 b
	BLSD	NS	NS	13.5
27 Jul 83				
Fertilizer	Zero-N	8010.9	1389.6 a	11.1 a
	$Ca(NO_3)_2$	17737.4	4973.1 b	89.9 c
	Urea	15195.0	4365.1 b	66.2 b
	BLSD	INT	694.4	9.9
Placement	Incorporated	12588.5	3954.9 b	55.9
	Surface	14707.1	3197.0 a	53.4
		INT		NS
Interaction	Zero-N (Inc.)	8190.6 a	1406.6	11.5
	Zero-N (Surf.)	7831.2 a	1372.6	10.7
	$Ca(NO_3)_2$ (Inc.)	15258.6 b	5408.0	89.4
	$Ca(NO_3)_2$ (Surf.)	20216.2 c	4538.1	90.3
	Urea (Inc.)	14316.2 b	5050.0	73.4
	Urea (Surf.)	16073.8 b	3680.1	59.0
	BLSD	2973.1	NS	NS
10 Aug 83				
Fertilizer	Zero-N	7310.0 a	1783.3 a	12.8 a
	$Ca(NO_3)_2$	12321.1 b	7567.5 b	92.2 c
	Urea	10631.5 b	7518.6 b	77.4 b
	BLSD	1740.5	1035.5	11.2
Placement	Incorporated	9810.5	6073.5	63.2
	Surface	10364.5	5172.8	58.4
		NS	NS	NS
Interaction	Zero-N (Inc.)	7514.2	1837.2	13.4
	Zero-N (Surf.)	7105.8	1729.4	12.1
	$Ca(NO_3)_2$ (Inc.)	11243.2	8226.6	92.0
	$Ca(NO_3)_2$ (Surf.)	13399.0	6908.4	92.4
	Urea (Inc.)	10674.2	8156.6	84.2
	Urea (Surf.)	10588.8	6880.7	70.6
		NS	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 16 Continued. Mean separations of plant weight and nitrogen uptake from main plots.

Sampling Date	Fertilizer Treatment	Plant N (µg/g)	Plant Dry Wt. (kg/ha)	N Uptake (kg/ha)
28 Jun 84				
Fertilizer	Zero-N	18966.9	376.1 a *	6.9 a
	$Ca(NO_3)_2$	36775.5	1038.0 b	37.8 c
	Urea	33864.8	882.2 b	29.6 b
	BLSD	INT	168.6	5.3
Placement	Incorporated	28833.4	779.3	24.4
	Surface	30904.7	751.6	25.1
		INT	NS	NS
Interaction	Zero-N (Inc.)	19899.2 a	320.8	6.2
	Zero-N (Surf.)	18034.6 a	431.4	7.6
	$Ca(NO_3)_2$ (Inc.)	33472.6 b	1097.0	36.5
	$Ca(NO_3)_2$ (Surf.)	40078.4 c	979.0	39.1
	Urea (Inc.)	33128.4 b	920.0	30.4
	Urea (Surf.)	34601.2 b	844.4	28.7
	BLSD	4852.8	NS	NS
25 Jul 84				
Fertilizer	Zero-N	6784.9 a	1431.6 a	9.9 a
	$Ca(NO_3)_2$	13619.2 c	4177.8 b	56.0 b
	Urea	12239.9 b	3924.3 b	51.8 b
	BLSD	1350.7	767.4	10.2
Placement	Incorporated	10798.4	3099.3	38.9
	Surface	11231.8	3256.6	40.7
		NS	NS	NS
Interaction	Zero-N (Inc.)	6926.0	1268.5	9.0
	Zero-N (Surf.)	6672.0	1594.8	10.7
	$Ca(NO_3)_2$ (Inc.)	13223.8	4399.1	56.8
	$Ca(NO_3)_2$ (Surf.)	14014.6	3956.6	55.3
	Urea (Inc.)	11471.0	3630.3	46.4
	Urea (Surf.)	13008.8	4218.4	56.1
		NS	NS	NS
08 Aug 84				
Fertilizer	Zero-N	7278.0 a	2197.7 a	15.1 a
	$Ca(NO_3)_2$	12220.1 b	6830.9 c	85.1 c
	Urea	11591.4 b	5909.1 b	68.7 b
	BLSD	1037.6	900.5	12.8
Placement	Incorporated	10039.7	4746.3	52.2
	Surface	10830.8	5212.2	62.0
		NS	NS	NS
Interaction	Zero-N (Inc.)	7108.0	1851.1	13.2
	Zero-N (Surf.)	7490.5	2544.3	17.4
	$Ca(NO_3)_2$ (Inc.)	11618.0	6805.1	79.8
	$Ca(NO_3)_2$ (Surf.)	12972.8	6856.8	91.6
	Urea (Inc.)	11393.2	5582.8	63.4
	Urea (Surf.)	11789.6	6235.4	74.1
		NS	NS	NS

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 17. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
NH_4^+ at 0-15 cm depth (all dates)				
Block (B)	4	51.1	12.8	0.19
Fertilizer Treatment (F)	5	8405.6	1681.1	24.92 *
FxB (error 1)	20	1349.2	67.5	
Sampling Date (D)	10	11858.1	1185.8	19.22 *
DxF	50	21938.4	438.8	7.11 *
DxB(T) (error 2)	240	14805.5	61.7	
Year (Y)	2	397.5	198.8	4.33 *
YxF	10	1707.4	170.7	3.72 *
YxB(T) (error 3)	48	2204.1	45.9	
YxD	17	3468.2	204.0	4.78 *
YxDxF	85	9811.0	115.4	2.70 *
error 4	366	15630.8	42.7	
NO_3^- at 0-15 cm depth (all dates)				
Block (B)	4	135.0	33.7	1.00
Fertilizer Treatment (F)	5	11674.9	2335.0	68.88 *
FxB (error 1)	20	678.0	33.9	
Sampling Date (D)	10	37141.2	3714.1	78.81 *
DxF	50	26604.1	532.1	11.29 *
DxB(T) (error 2)	239	11264.1	47.1	
Year (Y)	2	354.3	177.2	4.34 *
YxF	10	1120.3	112.0	2.75 *
YxB(T) (error 3)	48	1957.7	40.8	
YxD	18	2895.8	160.9	3.97 *
YxDxF	90	6503.7	72.3	1.78 *
error 4	378	15306.1	40.5	
NH_4^+ at 15-30 cm depth (all dates)				
Block (B)	4	37.0	9.2	5.53 *
Fertilizer Treatment (F)	5	45.8	9.2	5.47 *
FxB (error 1)	20	33.4	1.7	
Sampling Date (D)	10	207.6	20.8	10.77 *
DxF	50	183.2	3.7	1.90 *
DxB(T) (error 2)	239	460.4	1.9	
Year (Y)	2	54.9	27.4	20.13 *
YxF	10	29.4	2.9	2.15 *
YxB(T) (error 3)	48	65.4	1.4	
YxD	17	266.2	15.7	8.30 *
YxDxF	85	266.0	3.1	1.66 *
error 4	335	632.0	1.9	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
NO_3^- at 15-30 cm depth				
Block (B)	4	9.4	2.4	0.29
Fertilizer Treatment (F)	5	378.2	75.6	9.23 *
FxB (error 1)	20	163.8	8.2	
Sampling Date (D)	10	967.0	96.7	25.04 *
DxF	50	682.8	13.7	3.54 *
DxB(T) (error 2)	237	915.2	3.9	
Year (Y)	2	117.3	58.6	12.53 *
YxF	10	287.4	28.7	6.14 *
YxB(T) (error 3)	48	224.6	4.7	
YxD	18	651.1	36.2	9.21 *
YxDxF	90	1164.5	12.9	3.30 *
error 4	361	1417.5	3.9	
NH_4^+ at 30-60 cm depth (all dates)				
Block (B)	4	4.1	1.0	1.40
Fertilizer Treatment (F)	5	24.4	4.9	6.62 *
FxB (error 1)	20	14.7	0.7	
Sampling Date (D)	10	157.1	15.7	17.08 *
DxF	50	117.4	2.4	2.55 *
DxB(T) (error 2)	236	217.1	0.9	
Year (Y)	2	11.4	5.7	6.53 *
YxF	10	15.7	1.6	1.80
YxB(T) (error 3)	48	41.9	0.9	
YxD	17	66.5	3.9	4.04 *
YxDxF	85	105.4	1.2	1.28
error 4	334	323.1	1.0	
NO_3^- at 30-60 cm depth (all dates)				
Block (B)	4	32.5	8.1	2.18
Fertilizer Treatment (F)	5	87.2	17.4	4.69 *
FxB (error 1)	20	74.4	3.7	
Sampling Date (D)	10	708.2	70.8	18.11 *
DxF	50	1831.1	36.6	9.37 *
DxB(T) (error 2)	233	907.0	3.9	
Year (Y)	2	153.1	76.5	8.86 *
YxF	10	407.2	40.7	4.72 *
YxB(T) (error 3)	47	405.9	8.6	
YxD	18	523.8	29.1	9.96 *
YxDxF	90	740.7	8.2	2.82 *
error 4	370	1080.9	2.9	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
NH_4^+ at 60-90 cm depth (all dates)				
Block (B)	4	8.5	2.1	6.95 *
Fertilizer Treatment (F)	5	3.7	0.7	2.42
FxB (error 1)	20	6.1	0.3	
Sampling Date (D)	7	12.9	1.8	2.93 *
DxF	35	19.9	0.6	0.90
DxB(T) (error 2)	163	102.8	0.6	
Year (Y)	2	17.1	8.5	12.20 *
YxF	10	3.3	0.3	0.47
YxB(T) (error 3)	48	33.6	0.7	
YxD	7	15.0	2.2	3.28 *
YxDxF	35	23.9	0.7	1.04
error 4	123	80.6	0.7	
NO_3^- at 60-90 cm depth (all dates)				
Block (B)	4	6.0	1.5	2.11
Fertilizer Treatment (F)	5	9.4	1.9	2.65
FxB (error 1)	20	14.2	0.7	
Sampling Date (D)	7	22.0	3.2	10.92 *
DxF	35	18.8	0.5	1.86 *
DxB(T) (error 2)	164	46.8	0.3	
Year (Y)	2	9.0	4.5	8.93 *
YxF	10	9.1	0.9	1.80
YxB(T) (error 3)	46	23.2	0.5	
YxD	7	23.6	3.4	12.65 *
YxDxF	35	15.3	0.4	1.64 *
error 4	111	29.5	0.3	
NH_4^+ at 90+ cm depth (all dates)				
Block (B)	4	6.2	1.6	2.20
Fertilizer Treatment (F)	5	2.7	0.5	0.76
FxB (error 1)	19	13.4	0.7	
Sampling Date (D)	7	34.4	4.9	5.32 *
DxF	35	23.5	0.7	0.73
DxB(T) (error 2)	79	60.0	0.8	
Year (Y)	2	39.8	19.9	11.97 *
YxF	10	0.8	0.1	0.05
YxB(T) (error 3)	23	34.9	1.5	
YxD	5	6.7	1.3	2.23
YxDxF	19	13.6	0.7	1.19
error 4	11	6.6	0.6	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
NO_3^- at 90+ cm depth				
Block (B)	4	3.0	0.7	1.05
Fertilizer Treatment (F)	5	1.0	0.2	0.29
FxB (error 1)	19	13.5	0.7	
Sampling Date (D)	7	12.0	1.7	2.06
DxF	35	39.7	1.1	1.37
DxB(T) (error 2)	79	52.2	0.7	
Year (Y)	2	5.7	2.8	1.64
YxF	10	21.2	2.1	1.22
YxB(T) (error 3)	21	33.1	1.6	
YxD	5	6.9	1.4	6.79 *
YxDxF	19	1.6	0.1	0.41
error 4	12	2.4	0.2	
16 JUN 82, NH_4^+-N				
Block (B)	4	831.8	208.0	3.96 *
Fertilizer Treatment (F)	5	633.1	126.6	2.41
BxF (error 1)	20	1049.8	52.5	
Sampling Depth (D)	2	2090.2	1045.1	8.63 *
DxB (error 2)	8	968.7	121.1	
DxF	10	1791.2	179.1	3.17 *
DxFxB (error 3)	37	2093.4	56.6	
16 JUN 82, NO_3^--N				
Block (B)	4	797.9	199.5	2.77
Fertilizer Treatment (F)	5	1494.3	298.9	4.15 *
BxF (error 1)	20	1441.2	72.1	
Sampling Depth (D)	2	2818.8	1409.4	11.32 *
DxB (error 2)	8	996.0	124.5	
DxF	10	746.6	74.7	1.17
DxFxB (error 3)	37	2354.2	63.6	
15 JUL 82, NH_4^+-N				
Block (B)	4	7.1	1.8	2.38
Fertilizer Treatment (F)	5	7.9	1.6	2.13
BxF (error 1)	20	14.9	0.7	
Sampling Depth (D)	4	272.7	68.2	19.08 *
DxB (error 2)	16	57.2	3.6	
DxF	20	21.3	1.1	1.17
DxFxB (error 3)	59	53.8	0.9	
15 JUL 82, NO_3^--N				
Block (B)	4	11.6	2.9	0.35
Fertilizer Treatment (F)	5	85.7	17.1	2.04
BxF (error 1)	20	168.0	8.4	
Sampling Depth (D)	4	392.3	98.1	15.62 *
DxB (error 2)	16	100.5	6.3	
DxF	20	298.9	14.9	3.33 *
DxFxB (error 3)	62	277.9	4.5	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
28 JUL 82, NH_4^+-N				
Block (B)	4	6.4	1.6	1.61
Fertilizer Treatment (F)	5	12.2	2.3	2.45
BxF (error 1)	19	18.9	1.0	
Sampling Depth (D)	2	52.0	26.0	31.66 *
DxB (error 2)	8	6.6	0.8	
DxF	10	17.2	1.7	1.75
DxFxB (error 3)	29	28.5	1.0	
28 JUL 82, NO_3^--N				
Block (B)	4	2.2	0.5	1.01
Fertilizer Treatment (F)	5	18.7	3.7	6.93 *
BxF (error 1)	18	9.7	0.5	
Sampling Depth (D)	2	0.4	0.2	0.28
DxB (error 2)	8	5.5	0.7	
DxF	10	5.7	0.6	2.07
DxFxB (error 3)	34	9.3	0.3	
16 AUG 82, NH_4^+-N				
Block (B)	4	2.6	0.6	0.82
Fertilizer Treatment (F)	5	2.1	0.4	0.53
BxF (error 1)	20	15.7	0.8	
Sampling Depth (D)	4	90.8	22.7	44.47 *
DxB (error 2)	16	8.2	0.5	
DxF	20	12.4	0.6	0.96
DxFxB (error 3)	59	37.9	0.6	
16 AUG 82, NO_3^--N				
Block (B)	4	5.0	1.3	1.33
Fertilizer Treatment (F)	5	4.9	1.0	1.03
BxF (error 1)	20	18.9	1.0	
Sampling Depth (D)	4	20.0	5.0	7.18 *
DxB (error 2)	16	11.1	0.7	
DxF	20	29.3	1.5	2.24 *
DxFxB (error 3)	54	35.3	0.6	
01 SEP 82, NH_4^+-N				
Block (B)	4	63.0	15.8	8.40 *
Fertilizer Treatment (F)	5	12.6	2.5	1.35
BxF (error 1)	20	37.5	1.9	
Sampling Depth (D)	2	117.6	58.8	13.08 *
DxB (error 2)	8	36.0	4.5	
DxF	10	8.9	0.9	0.83
DxFxB (error 3)	37	39.6	1.1	
01 SEP 82, NO_3^--N				
Block (B)	4	8.3	2.1	11.21 *
Fertilizer Treatment (F)	5	1.7	0.3	1.87
BxF (error 1)	20	3.7	0.2	
Sampling Depth (D)	2	6.8	3.4	2.18
DxB (error 2)	8	12.5	1.6	
DxF	10	1.2	0.1	0.80
DxFxB (error 3)	32	4.9	0.2	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
16 SEP 82, NH_4^+-N				
Block (B)	3	3.4	1.1	5.02 *
Fertilizer Treatment (F)	5	1.9	0.4	1.69
BxF (error 1)	15	3.3	0.2	
Sampling Depth (D)	4	69.7	17.4	47.75 *
DxB (error 2)	12	4.4	0.4	
DxF	19	4.9	0.3	2.22 *
DxFxB (error 3)	43	5.0	0.1	
16 SEP 82, NO_3^--N				
Block (B)	3	88.9	29.6	6.09 *
Fertilizer Treatment (F)	5	19.8	4.0	0.81
BxF (error 1)	15	73.0	4.9	
Sampling Depth (D)	4	32.4	8.1	5.23 *
DxB (error 2)	12	18.6	1.6	
DxF	19	38.8	2.0	1.37
DxFxB (error 3)	39	58.0	1.5	
16 SEP 82, NH_4^+-N		- missing-		
01 OCT 82, NO_3^--N				
Block (B)	4	19.0	4.8	2.48
Fertilizer Treatment (F)	5	8.6	1.7	0.90
BxF (error 1)	19	36.3	1.9	
Sampling Depth (D)	2	2.8	1.4	3.24
DxB (error 2)	8	3.5	0.4	
DxF	10	8.8	0.9	1.43
DxFxB (error 3)	35	21.5	0.6	
12 OCT 82, NH_4^+-N				
Block (B)	4	469.8	117.4	12.66 *
Fertilizer Treatment (F)	5	32.8	6.6	0.71
BxF (error 1)	15	139.1	9.3	
Sampling Depth (D)	4	322.5	80.6	2.56
DxB (error 2)	15	473.2	31.6	
DxF	19	236.0	12.4	1.78
DxFxB (error 3)	38	264.6	7.0	
12 OCT 82, NO_3^--N				
Block (B)	4	15.8	4.0	2.42
Fertilizer Treatment (F)	5	9.9	2.0	1.21
BxF (error 1)	14	22.9	1.6	
Sampling Depth (D)	4	1.4	0.4	0.92
DxB (error 2)	15	5.8	0.4	
DxF	19	11.8	0.6	0.91
DxFxB (error 3)	30	20.5	0.7	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
19 MAY 83, NH_4^+-N				
Block (B)	4	1.0	0.2	0.31
Fertilizer Treatment (F)	5	17.3	3.5	4.20 *
BxF (error 1)	20	16.5	0.8	
Sampling Depth (D)	4	412.7	103.2	161.90 *
DxB (error 2)	12	7.6	0.6	
DxF	15	45.4	3.0	3.80 *
DxFxB (error 3)	48	38.2	0.8	
19 MAY 83, NO_3^--N				
Block (B)	4	19.4	4.9	1.07
Fertilizer Treatment (F)	5	66.1	13.2	2.90 *
BxF (error 1)	20	91.1	4.6	
Sampling Depth (D)	4	571.7	142.9	56.84 *
DxB (error 2)	12	30.2	2.5	
DxF	15	50.3	3.4	1.79
DxFxB (error 3)	49	91.7	1.9	
01 JUN 83, NH_4^+-N				
Block (B)	4	789.4	197.4	1.39
Fertilizer Treatment (F)	5	4119.4	823.9	5.78 *
BxF (error 1)	20	2849.6	142.5	
Sampling Depth (D)	2	4385.2	2192.6	20.52 *
DxB (error 2)	8	854.7	106.8	
DxF	10	5067.8	506.8	6.68 *
DxFxB (error 3)	37	2809.1	75.9	
01 JUN 83, NO_3^--N				
Block (B)	4	308.0	77.0	0.73
Fertilizer Treatment (F)	5	7421.0	1484.2	14.04 *
BxF (error 1)	20	2113.6	105.7	
Sampling Depth (D)	2	3534.6	1767.3	11.71 *
DxB (error 2)	8	1206.9	150.9	
DxF	10	4368.6	436.9	6.09 *
DxFxB (error 3)	36	2581.4	71.7	
15 JUN 83, NH_4^+-N				
Block (B)	4	113.7	5.3	0.85
Fertilizer Treatment (F)	5	1197.5	239.5	7.18 *
BxF (error 1)	20	666.9	33.4	
Sampling Depth (D)	4	3657.1	914.3	17.27 *
DxB (error 2)	14	741.2	52.9	
DxF	20	5000.5	250.0	8.40 *
DxFxB (error 3)	60	1786.6	29.8	
15 JUN 83, NO_3^--N				
Block (B)	4	429.8	107.4	1.65
Fertilizer Treatment (F)	5	2145.9	429.2	6.60 *
BxF (error 1)	20	1300.5	65.0	
Sampling Depth (D)	4	11420.0	2855.0	36.17 *
DxB (error 2)	14	1105.2	78.9	
DxF	20	8906.4	445.3	7.85 *
DxFxB (error 3)	55	3120.8	56.7	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df[†]	SS	MS	F
28 JUN 83, NH_4^+-N				
Block (B)	4	424.7	106.2	1.38
Fertilizer Treatment (F)	5	2665.3	533.1	6.94 *
BxF (error 1)	20	1537.2	76.9	
Sampling Depth (D)	2	816.5	408.2	28.27 *
DxB (error 2)	8	115.5	14.4	
DxF	10	1214.8	121.5	6.00 *
DxFxB (error 3)	37	749.7	20.3	
28 JUN 83, NO_3^--N				
Block (B)	4	647.8	162.0	1.56
Fertilizer Treatment (F)	5	4797.8	959.6	9.22 *
BxF (error 1)	20	2080.6	104.0	
Sampling Depth (D)	2	1939.3	969.6	48.25 *
DxB (error 2)	8	160.8	20.1	
DxF	10	1379.2	137.9	4.78 *
DxFxB (error 3)	37	1067.6	28.8	
13 JUL 83, NH_4^+-N				
Block (B)	4	150.6	37.7	0.46
Fertilizer Treatment (F)	5	1593.2	318.6	3.91 *
BxF (error 1)	20	1631.5	81.6	
Sampling Depth (D)	4	4128.5	1032.1	10.03 *
DxB (error 2)	15	1544.2	102.9	
DxF	20	8189.4	409.5	4.43 *
DxFxB (error 3)	55	5089.0	92.5	
13 JUL 83, NO_3^--N				
Block (B)	4	71.7	17.9	0.76
Fertilizer Treatment (F)	5	249.4	49.9	2.12
BxF (error 1)	20	469.6	23.5	
Sampling Depth (D)	4	874.5	218.6	12.95 *
DxB (error 2)	15	253.3	16.9	
DxF	20	1580.2	79.0	4.78 *
DxFxB (error 3)	54	892.8	16.5	
27 JUL 83, NH_4^+-N				
Block (B)	4	62.8	15.7	4.91 *
Fertilizer Treatment (F)	5	46.4	9.3	2.90 *
BxF (error 1)	20	64.0	3.2	
Sampling Depth (D)	2	456.6	228.3	36.22 *
DxB (error 2)	8	50.4	6.3	
DxF	10	54.1	5.4	1.38
DxFxB (error 3)	37	145.1	3.9	
27 JUL 83, NO_3^--N				
Block (B)	4	7.7	1.9	1.88
Fertilizer Treatment (F)	5	64.1	12.8	12.58 *
BxF (error 1)	20	20.4	1.0	
Sampling Depth (D)	2	19.6	9.8	2.45
DxB (error 2)	8	32.1	4.0	
DxF	10	33.4	3.3	3.76 *
DxFxB (error 3)	35	31.1	0.9	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
10 AUG 83, NH_4^+-N				
Block (B)	4	7.3	1.8	2.54
Fertilizer Treatment (F)	5	2.6	0.5	0.73
BxF (error 1)	20	14.4	0.7	
Sampling Depth (D)	4	239.5	59.9	28.00 *
DxB (error 2)	16	34.2	2.1	
DxF	20	26.0	1.3	1.55
DxFxB (error 3)	60	50.2	0.8	
10 AUG 83, NO_3^--N				
Block (B)	4	2.3	0.6	2.77
Fertilizer Treatment (F)	5	2.1	0.4	1.95
BxF (error 1)	20	4.2	0.2	
Sampling Depth (D)	4	4.0	1.0	3.05 *
DxB (error 2)	16	5.2	0.3	
DxF	20	6.0	0.3	1.69
DxFxB (error 3)	58	10.2	0.2	
23 AUG 83, NH_4^+-N				
Block (B)	4	24.4	6.1	7.85 *
Fertilizer Treatment (F)	5	4.0	0.8	1.03
BxF (error 1)	20	15.6	0.8	
Sampling Depth (D)	2	105.4	52.7	46.79 *
DxB (error 2)	8	9.0	1.1	
DxF	10	23.9	2.4	2.18 *
DxFxB (error 3)	34	37.3	1.1	
23 AUG 83, NO_3^--N				
Block (B)	4	1.6	0.4	1.10
Fertilizer Treatment (F)	5	6.1	1.2	3.43 *
BxF (error 1)	20	7.1	0.4	
Sampling Depth (D)	2	1.5	0.7	3.48
DxB (error 2)	8	1.7	0.2	
DxF	10	6.9	0.7	2.01
DxFxB (error 3)	35	12.0	0.3	
07 SEP 83, NH_4^+-N				
Block (B)	4	8.6	2.1	3.16 *
Fertilizer Treatment (F)	5	1.4	0.3	0.40
BxF (error 1)	20	13.6	0.7	
Sampling Depth (D)	4	131.0	32.7	22.62 *
DxB (error 2)	15	21.7	1.4	
DxF	19	5.8	0.3	0.63
DxFxB (error 3)	59	28.4	0.5	
07 SEP 83, NO_3^--N				
Block (B)	4	0.7	0.2	1.63
Fertilizer Treatment (F)	5	0.6	0.1	1.06
BxF (error 1)	20	2.2	0.1	
Sampling Depth (D)	4	0.6	0.2	2.93
DxB (error 2)	15	0.8	0.1	
DxF	19	2.2	0.1	2.51 *
DxFxB (error 3)	59	2.7	0.1	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
22 SEP 83, NH_4^+-N				
Block (B)	4	5.0	1.3	8.11 *
Fertilizer Treatment (F)	5	1.9	0.4	2.48
BxF (error 1)	20	3.1	0.2	
Sampling Depth (D)	2	46.1	23.1	36.73 *
DxB (error 2)	8	5.0	0.6	
DxF	10	5.1	0.5	3.22 *
DxFxB (error 3)	34	5.4	0.2	
22 SEP 83, NO_3^--N				
Block (B)	4	0.5	0.1	1.75
Fertilizer Treatment (F)	5	1.5	0.3	4.30 *
BxF (error 1)	20	1.4	0.1	
Sampling Depth (D)	2	1.0	0.5	6.95 *
DxB (error 2)	8	0.6	0.1	
DxF	10	1.5	0.2	1.97
DxFxB (error 3)	35	2.6	0.1	
05 OCT 83, NH_4^+-N				
Block (B)	4	10.6	2.6	2.29
Fertilizer Treatment (F)	5	4.7	0.9	0.82
BxF (error 1)	20	23.1	1.2	
Sampling Depth (D)	4	103.8	26.0	25.39 *
DxB (error 2)	15	15.3	1.0	
DxF	20	16.4	0.8	1.50
DxFxB (error 3)	50	27.3	0.6	
05 OCT 83, NO_3^--N				
Block (B)	4	1.0	0.2	0.40
Fertilizer Treatment (F)	5	3.2	0.6	1.08
BxF (error 1)	20	11.9	0.6	
Sampling Depth (D)	4	6.4	1.6	5.14 *
DxB (error 2)	15	4.6	0.3	
DxF	20	9.4	0.5	2.35 *
DxFxB (error 3)	52	10.4	0.2	
11 MAY 84, NH_4^+-N				
Block (B)	4	27.0	6.8	0.69
Fertilizer Treatment (F)	5	90.8	18.2	1.85
BxF (error 1)	20	196.1	9.8	
Sampling Depth (D)	4	373.8	93.4	16.87 *
DxB (error 2)	12	66.4	5.5	
DxF	15	242.6	16.2	2.36 *
DxFxB (error 3)	40	274.4	6.9	
11 MAY 84, NO_3^--N				
Block (B)	4	8.0	2.0	5.97 *
Fertilizer Treatment (F)	5	9.0	1.8	5.36 *
BxF (error 1)	20	6.7	0.3	
Sampling Depth (D)	4	115.4	28.8	28.58 *
DxB (error 2)	12	12.1	1.0	
DxF	15	21.2	1.4	3.59 *
DxFxB (error 3)	39	15.3	0.4	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
31 MAY 84, NH_4^+-N				
Block (B)	4	199.3	49.8	1.37
Fertilizer Treatment (F)	5	2580.4	516.1	14.16 *
BxF (error 1)	20	729.1	36.5	
Sampling Depth (D)	2	2730.2	1365.1	32.48 *
DxB (error 2)	8	336.2	42.0	
DxF	10	3276.0	327.6	11.24 *
DxFxB (error 3)	35	1020.0	29.1	
31 MAY 84, NO_3^--N				
Block (B)	4	35.3	8.8	0.22
Fertilizer Treatment (F)	5	1927.3	385.5	9.78 *
BxF (error 1)	20	788.2	39.4	
Sampling Depth (D)	2	3325.7	1662.8	141.08 *
DxB (error 2)	8	94.3	11.8	
DxF	10	2027.0	202.7	8.92 *
DxFxB (error 3)	35	795.6	22.7	
13 JUN 84, NH_4^+-N				
Block (B)	4	20.7	5.2	0.30
Fertilizer Treatment (F)	5	117.9	23.6	1.35
BxF (error 1)	20	349.7	17.5	
Sampling Depth (D)	4	964.9	241.2	19.55 *
DxB (error 2)	15	185.0	12.3	
DxF	20	991.0	49.6	4.69 *
DxFxB (error 3)	51	538.4	10.6	
13 JUN 84, NO_3^--N				
Block (B)	4	233.1	58.3	1.88
Fertilizer Treatment (F)	5	1552.8	310.6	10.00 *
BxF (error 1)	20	620.8	31.0	
Sampling Depth (D)	4	8900.6	2225.1	68.70 *
DxB (error 2)	15	485.8	32.4	
DxF	20	8868.4	443.4	18.31 *
DxFxB (error 3)	58	1404.3	24.2	
28 JUN 84, NH_4^+-N				
Block (B)	4	235.5	58.9	2.00
Fertilizer Treatment (F)	5	1787.0	357.4	12.14 *
BxF (error 1)	19	559.5	29.4	
Sampling Depth (D)	2	1939.0	969.5	45.43 *
DxB (error 2)	8	170.7	21.3	
DxF	10	2242.2	224.2	13.57 *
DxFxB (error 3)	34	561.7	16.5	
28 JUN 84, NO_3^--N				
Block (B)	4	440.4	110.1	1.42
Fertilizer Treatment (F)	5	1097.4	219.5	2.83 *
BxF (error 1)	19	1472.5	77.5	
Sampling Depth (D)	2	2550.3	1275.1	18.64 *
DxB (error 2)	8	547.3	68.4	
DxF	10	1986.1	198.6	2.81 *
DxFxB (error 3)	34	2406.9	70.8	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
12 JUL 84, NH_4^+-N				
Block (B)	4	36.4	9.1	7.04 *
Fertilizer Treatment (F)	5	36.4	7.3	5.62 *
BxF (error 1)	20	25.9	1.3	
Sampling Depth (D)	4	601.6	150.4	28.55 *
DxB (error 2)	16	84.3	5.3	
DxF	20	129.1	6.4	5.49 *
DxFxB (error 3)	68	80.0	1.2	
12 JUL 84, NO_3^--N				
Block (B)	4	12.2	3.1	2.43
Fertilizer Treatment (F)	5	11.7	2.3	1.86
BxF (error 1)	20	25.2	1.3	
Sampling Depth (D)	4	27.0	6.8	18.98 *
DxB (error 2)	16	5.7	0.4	
DxF	20	47.0	2.4	2.22 *
DxFxB (error 3)	66	69.9	1.1	
25 JUL 84, NH_4^+-N				
Block (B)	4	10.6	2.6	2.34
Fertilizer Treatment (F)	5	6.2	1.2	1.09
BxF (error 1)	20	22.6	1.1	
Sampling Depth (D)	2	145.8	72.9	44.02 *
DxB (error 2)	8	13.2	1.7	
DxF	10	4.5	0.4	0.63
DxFxB (error 3)	32	22.8	0.7	
25 JUL 84, NO_3^--N				
Block (B)	4	6.0	1.5	2.93 *
Fertilizer Treatment (F)	5	14.7	2.9	5.74 *
BxF (error 1)	20	10.2	0.5	
Sampling Depth (D)	2	1.6	0.8	2.71
DxB (error 2)	8	2.3	0.3	
DxF	10	12.6	1.3	4.41 *
DxFxB (error 3)	34	9.7	0.3	
08 AUG 84, NH_4^+-N				
Block (B)	4	61.5	15.4	32.38 *
Fertilizer Treatment (F)	5	5.0	1.0	2.13
BxF (error 1)	20	9.5	0.5	
Sampling Depth (D)	4	225.4	56.4	49.95 *
DxB (error 2)	16	18.0	1.1	
DxF	20	29.3	1.5	2.44 *
DxFxB (error 3)	67	40.2	0.6	
08 AUG 84, NO_3^--N				
Block (B)	4	2.1	0.5	2.14
Fertilizer Treatment (F)	5	3.1	0.6	2.56
BxF (error 1)	20	4.9	0.2	
Sampling Depth (D)	4	0.7	0.2	1.29
DxB (error 2)	16	2.2	0.1	
DxF	20	7.5	0.4	3.17 *
DxFxB (error 3)	65	7.7	0.1	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
22 AUG 84, NH_4^+-N				
Block (B)	4	60.1	15.0	40.16 *
Fertilizer Treatment (F)	5	3.1	0.6	1.66
BxF (error 1)	19	7.1	0.4	
Sampling Depth (D)	2	57.8	28.9	22.89 *
DxB (error 2)	8	10.1	1.3	
DxF	10	6.0	0.6	1.29
DxFxB (error 3)	36	16.6	0.5	
22 AUG 84, NO_3^--N				
Block (B)	4	4.5	1.1	2.54
Fertilizer Treatment (F)	5	8.2	1.6	3.67 *
BxF (error 1)	20	8.9	0.4	
Sampling Depth (D)	2	1.2	0.6	1.82
DxB (error 2)	8	2.6	0.3	
DxF	10	3.0	0.3	1.62
DxFxB (error 3)	37	6.8	0.2	
05 SEP 84, NH_4^+-N				
Block (B)	4	6.7	1.7	4.31 *
Fertilizer Treatment (F)	5	1.1	0.2	0.55
BxF (error 1)	20	7.8	0.4	
Sampling Depth (D)	4	205.8	51.5	25.76 *
DxB (error 2)	15	30.0	2.0	
DxF	20	15.0	0.8	1.96 *
DxFxB (error 3)	69	26.5	0.4	
05 SEP 84, NO_3^--N				
Block (B)	4	4.1	1.0	1.55
Fertilizer Treatment (F)	5	8.4	1.7	2.50
BxF (error 1)	20	13.4	0.7	
Sampling Depth (D)	4	6.2	1.5	3.91 *
DxB (error 2)	15	5.9	0.4	
DxF	20	18.1	0.9	2.47 *
DxFxB (error 3)	67	24.5	0.4	
18 SEP 84, NH_4^+-N				
Block (B)	4	58.8	14.7	18.87 *
Fertilizer Treatment (F)	5	0.3	0.1	0.07
BxF (error 1)	20	15.6	0.8	
Sampling Depth (D)	2	186.4	93.2	18.32 *
DxB (error 2)	8	40.7	5.1	
DxF	10	8.8	0.9	1.66
DxFxB (error 3)	37	19.5	0.5	
18 SEP 84, NO_3^--N				
Block (B)	4	5.2	1.3	1.88
Fertilizer Treatment (F)	5	14.6	2.9	4.18 *
BxF (error 1)	20	13.9	0.7	
Sampling Depth (D)	2	10.0	5.0	6.56 *
DxB (error 2)	8	6.1	0.8	
DxF	10	12.9	1.3	1.43
DxFxB (error 3)	39	35.3	0.9	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 17 Continued. ANOVA tables of available nitrogen in soil samples from main plots.

Source	df†	SS	MS	F
02 OCT 84, NH_4^+-N				
Block (B)	4	20.1	5.0	4.74 *
Fertilizer Treatment (F)	5	21.7	4.3	4.09 *
BxF (error 1)	20	21.2	1.1	
Sampling Depth (D)	4	178.9	44.7	13.43 *
DxB (error 2)	16	53.3	3.3	
DxF	20	19.1	1.0	1.19
DxFxB (error 3)	65	52.1	0.8	
02 OCT 84, NO_3^--N				
Block (B)	4	7.7	1.9	1.37
Fertilizer Treatment (F)	5	29.1	5.8	4.14 *
BxF (error 1)	20	28.2	1.4	
Sampling Depth (D)	4	50.6	12.6	15.36 *
DxB (error 2)	16	13.2	0.8	
DxF	20	45.1	2.3	2.18 *
DxFxB (error 3)	63	65.2	1.0	
20 MAY 85, NH_4^+-N				
Block (B)	4	5.3	1.3	1.04
Fertilizer Treatment (F)	5	23.4	4.7	3.67 *
BxF (error 1)	20	25.5	1.3	
Sampling Depth (D)	4	150.1	37.5	26.60 *
DxB (error 2)	15	21.2	1.4	
DxF	20	23.4	1.2	0.85
DxFxB (error 3)	47	64.6	1.4	
20 MAY 85, NO_3^--N				
Block (B)	4	6.9	1.7	1.72
Fertilizer Treatment (F)	5	20.5	4.1	4.07 *
BxF (error 1)	20	20.2	1.0	
Sampling Depth (D)	4	207.4	51.8	91.06 *
DxB (error 2)	15	8.5	0.6	
DxF	20	19.9	1.0	2.91 *
DxFxB (error 3)	52	17.8	0.3	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 18. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
16 JUN 82			
all	Zero-N (Inc.)	2.5	3.5 a *
all	Zero-N (Surf.)	2.9	3.4 a
all	$Ca(NO_3)_2$ (Inc.)	4.5	15.1 b
all	$Ca(NO_3)_2$ (Surf.)	3.8	10.1 ab
all	Urea (Inc.)	8.7	5.2 a
all	Urea (Surf.)	11.0	6.8 a
	BLSD	INT	6.8
0-15 cm	all	12.6	14.9 b
15-30 cm	all	2.5	6.0 a
30-60 cm	all	1.6	1.2 a
	BLSD	INT	6.9
0-15 cm	Zero-N (Inc.)	4.5 a	7.6
0-15 cm	Zero-N (Surf.)	3.9 a	6.2
0-15 cm	$Ca(NO_3)_2$ (Inc.)	9.6 a	27.9
0-15 cm	$Ca(NO_3)_2$ (Surf.)	5.5 a	21.2
0-15 cm	Urea (Inc.)	22.6 b	12.0
0-15 cm	Urea (Surf.)	27.6 b	14.7
15-30 cm	Zero-N (Inc.)	2.0 a	2.4
15-30 cm	Zero-N (Surf.)	2.6 a	2.8
15-30 cm	$Ca(NO_3)_2$ (Inc.)	2.6 a	15.7
15-30 cm	$Ca(NO_3)_2$ (Surf.)	3.6 a	6.8
15-30 cm	Urea (Inc.)	1.8 a	3.2
15-30 cm	Urea (Surf.)	2.2 a	4.3
30-60 cm	Zero-N (Inc.)	1.3 a	0.5
30-60 cm	Zero-N (Surf.)	1.9 a	0.6
30-60 cm	$Ca(NO_3)_2$ (Inc.)	1.4 a	1.8
30-60 cm	$Ca(NO_3)_2$ (Surf.)	2.3 a	2.4
30-60 cm	Urea (Inc.)	1.6 a	0.6
30-60 cm	Urea (Surf.)	1.4 a	0.9
	BLSD	10.9	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
15 JUL 82			
all	Zero-N (Inc.)	1.3	0.6
all	Zero-N (Surf.)	1.4	0.9
all	$Ca(NO_3)_2$ (Inc.)	1.7	3.1
all	$Ca(NO_3)_2$ (Surf.)	1.6	2.6
all	Urea (Inc.)	1.8	3.0
all	Urea (Surf.)	2.1	1.5
		NS *	NS
0-15 cm	all	4.4 b	5.3
15-30 cm	all	1.2 a	2.2
30-60 cm	all	0.6 a	0.8
60-90 cm	all	0.7 a	0.7
90+ cm	all	1.1 a	0.4
	BLSD	1.0	NS
0-15 cm	Zero-N (Inc.)	3.0	0.4 a
0-15 cm	Zero-N (Surf.)	4.0	0.6 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.6	8.8 d
0-15 cm	$Ca(NO_3)_2$ (Surf.)	4.1	7.9 d
0-15 cm	Urea (Inc.)	5.0	9.4 d
0-15 cm	Urea (Surf.)	5.6	3.9 c
15-30 cm	Zero-N (Inc.)	1.4	1.1 abc
15-30 cm	Zero-N (Surf.)	1.1	0.9 ab
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.0	4.0 c
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.8	1.8 abc
15-30 cm	Urea (Inc.)	1.5	3.8 bc
15-30 cm	Urea (Surf.)	1.3	1.1 abc
30-60 cm	Zero-N (Inc.)	0.4	0.9 a
30-60 cm	Zero-N (Surf.)	0.4	1.0 ab
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.3	0.6 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.9	0.8 a
30-60 cm	Urea (Inc.)	0.8	1.1 abc
30-60 cm	Urea (Surf.)	0.4	0.7 a
60-90 cm	Zero-N (Inc.)	0.4	0.5 a
60-90 cm	Zero-N (Surf.)	0.4	1.3 abc
60-90 cm	$Ca(NO_3)_2$ (Inc.)	1.0	0.4 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.7	0.5 a
60-90 cm	Urea (Inc.)	0.4	0.6 a
60-90 cm	Urea (Surf.)	1.0	0.8 a
90+ cm	Zero-N (Inc.)	1.4	0.2 a
90+ cm	Zero-N (Surf.)	0.5	0.8 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	1.2	0.5 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.7	0.4 a
90+ cm	Urea (Inc.)	0.7	0.4 a
90+ cm	Urea (Surf.)	1.7	0.5 a
	BLSD	NS	2.9

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
28 JUL 82			
all	Zero-N (Inc.)	0.8	0.6 a *
all	Zero-N (Surf.)	0.7	0.5 a
all	$Ca(NO_3)_2$ (Inc.)	1.9	1.6 bc
all	$Ca(NO_3)_2$ (Surf.)	1.3	1.9 c
all	Urea (Inc.)	1.0	1.1 ab
all	Urea (Surf.)	1.8	1.0 a
	BLSD	NS	0.6
0-15 cm	all	2.9 b	1.2
15-30 cm	all	0.3 a	1.1
30-60 cm	all	0.2 a	1.0
	BLSD	0.5	NS
0-15 cm	Zero-N (Inc.)	1.8	0.4
0-15 cm	Zero-N (Surf.)	1.8	0.4
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.3	2.4
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.2	1.8
0-15 cm	Urea (Inc.)	2.2	1.2
0-15 cm	Urea (Surf.)	4.4	1.2
15-30 cm	Zero-N (Inc.)	0.2	0.6
15-30 cm	Zero-N (Surf.)	0.1	0.5
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.7	1.5
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.2	2.0
15-30 cm	Urea (Inc.)	0.2	1.1
15-30 cm	Urea (Surf.)	0.3	0.9
30-60 cm	Zero-N (Inc.)	0.1	0.7
30-60 cm	Zero-N (Surf.)	0.1	0.7
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.7	1.1
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.2	1.8
30-60 cm	Urea (Inc.)	0.1	1.0
30-60 cm	Urea (Surf.)	0.1	0.8
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
16 AUG 82			
all	Zero-N (Inc.)	1.5	0.6
all	Zero-N (Surf.)	1.4	0.7
all	$Ca(NO_3)_2$ (Inc.)	1.4	1.4
all	$Ca(NO_3)_2$ (Surf.)	1.4	0.8
all	Urea (Inc.)	1.2	1.1
all	Urea (Surf.)	1.5	0.6
		NS *	INT
0-15 cm	all	3.0 c	1.7
15-30 cm	all	1.1 b	0.8
30-60 cm	all	1.0 ab	0.7
60-90 cm	all	0.7 a	0.6
90+ cm	all	0.9 ab	0.4
	BLSD	0.3	INT
0-15 cm	Zero-N (Inc.)	3.3	0.9 ab
0-15 cm	Zero-N (Surf.)	2.2	0.5 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.3	3.9 c
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.5	1.3 ab
0-15 cm	Urea (Inc.)	2.8	2.1 b
0-15 cm	Urea (Surf.)	3.6	1.0 ab
15-30 cm	Zero-N (Inc.)	0.9	0.5 a
15-30 cm	Zero-N (Surf.)	1.2	0.5 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.9	0.7 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.1	0.8 a
15-30 cm	Urea (Inc.)	1.2	1.4 ab
15-30 cm	Urea (Surf.)	1.3	0.6 a
30-60 cm	Zero-N (Inc.)	0.9	0.6 a
30-60 cm	Zero-N (Surf.)	1.7	0.8 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.7	0.6 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	1.1	0.8 a
30-60 cm	Urea (Inc.)	0.6	0.6 a
30-60 cm	Urea (Surf.)	0.8	0.6 a
60-90 cm	Zero-N (Inc.)	0.8	0.4 a
60-90 cm	Zero-N (Surf.)	0.6	0.9 ab
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.5	0.5 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	1.0	0.7 a
60-90 cm	Urea (Inc.)	0.7	0.8 a
60-90 cm	Urea (Surf.)	0.6	0.6 a
90+ cm	Zero-N (Inc.)	1.2	0.3 a
90+ cm	Zero-N (Surf.)	0.6	0.4 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	1.5	0.3 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.8	0.5 a
90+ cm	Urea (Inc.)	0.6	0.4 a
90+ cm	Urea (Surf.)	0.4	0.4 a
	BLSD	NS	1.3

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
01 SEP 82			
all	Zero-N (Inc.)	2.2	0.7
all	Zero-N (Surf.)	2.8	1.1
all	$Ca(NO_3)_2$ (Inc.)	2.0	1.0
all	$Ca(NO_3)_2$ (Surf.)	2.6	1.2
all	Urea (Inc.)	1.7	0.8
all	Urea (Surf.)	2.7	0.8
		NS *	NS
0-15 cm	all	3.9 b	1.3
15-30 cm	all	1.9 a	0.7
30-60 cm	all	1.1 a	0.7
	BLSD	1.3	NS
0-15 cm	Zero-N (Inc.)	4.1	1.2
0-15 cm	Zero-N (Surf.)	4.5	1.7
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.4	1.4
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.8	1.8
0-15 cm	Urea (Inc.)	2.7	1.0
0-15 cm	Urea (Surf.)	5.0	0.8
15-30 cm	Zero-N (Inc.)	1.0	0.4
15-30 cm	Zero-N (Surf.)	2.5	0.7
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.8	0.8
15-30 cm	$Ca(NO_3)_2$ (Surf.)	2.4	0.9
15-30 cm	Urea (Inc.)	1.5	0.6
15-30 cm	Urea (Surf.)	2.1	0.9
30-60 cm	Zero-N (Inc.)	1.3	0.6
30-60 cm	Zero-N (Surf.)	1.1	0.6
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.9	0.8
30-60 cm	$Ca(NO_3)_2$ (Surf.)	1.2	0.7
30-60 cm	Urea (Inc.)	0.8	0.8
30-60 cm	Urea (Surf.)	1.1	0.8
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
16 SEP 82			
all	Zero-N (Inc.)	1.2	2.6
all	Zero-N (Surf.)	1.1	3.0
all	$Ca(NO_3)_2$ (Inc.)	1.4	2.4
all	$Ca(NO_3)_2$ (Surf.)	1.0	4.8
all	Urea (Inc.)	1.1	2.1
all	Urea (Surf.)	1.4	2.5
		INT *	NS
0-15 cm	all	2.8	3.8 c
15-30 cm	all	0.9	3.0 bc
30-60 cm	all	0.7	2.7 ab
60-90 cm	all	0.6	2.3 ab
90+ cm	all	0.7	1.9 a
	BLSD	INT	1.0
0-15 cm	Zero-N (Inc.)	2.3 f	2.9
0-15 cm	Zero-N (Surf.)	2.3 f	4.8
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.6 g	3.4
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.8 fg	6.4
0-15 cm	Urea (Inc.)	2.7 fg	2.5
0-15 cm	Urea (Surf.)	3.0 g	2.9
15-30 cm	Zero-N (Inc.)	1.3 e	2.4
15-30 cm	Zero-N (Surf.)	0.7 abcd	3.1
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.0 bcde	3.0
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.5 abcd	4.9
15-30 cm	Urea (Inc.)	0.9 abcde	2.2
15-30 cm	Urea (Surf.)	1.0 cde	2.0
30-60 cm	Zero-N (Inc.)	0.8 abcde	2.3
30-60 cm	Zero-N (Surf.)	0.7 abcd	3.9
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.8 abcde	2.4
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.5 abc	3.6
30-60 cm	Urea (Inc.)	0.4 ab	2.1
30-60 cm	Urea (Surf.)	0.7 abcde	2.2
60-90 cm	Zero-N (Inc.)	0.7 abcd	2.1
60-90 cm	Zero-N (Surf.)	0.6 abcd	2.0
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.7 abcd	1.7
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.4 ab	3.6
60-90 cm	Urea (Inc.)	0.7 abcd	0.5
60-90 cm	Urea (Surf.)	0.6 abcd	3.4
90+ cm	Zero-N (Inc.)	0.3 a	3.7
90+ cm	Zero-N (Surf.)	1.1 de	0.5
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.9 abcde	0.4
90+ cm	$Ca(NO_3)_2$ (Surf.)		
90+ cm	Urea (Inc.)	0.5 abcd	2.8
90+ cm	Urea (Surf.)	1.0 cde	0.6
	BLSD	0.6	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
01 OCT 82			
all	Zero-N (Inc.)		1.4
all	Zero-N (Surf.)		1.3
all	$Ca(NO_3)_2$ (Inc.)		1.8
all	$Ca(NO_3)_2$ (Surf.)		2.2
all	Urea (Inc.)		1.5
all	Urea (Surf.)		1.9
			NS *
0-15 cm	all		1.9
15-30 cm	all		1.8
30-60 cm	all		1.4
			NS
0-15 cm	Zero-N (Inc.)		1.7
0-15 cm	Zero-N (Surf.)		1.3
0-15 cm	$Ca(NO_3)_2$ (Inc.)		1.9
0-15 cm	$Ca(NO_3)_2$ (Surf.)		3.0
0-15 cm	Urea (Inc.)		1.9
0-15 cm	Urea (Surf.)		1.5
15-30 cm	Zero-N (Inc.)		1.1
15-30 cm	Zero-N (Surf.)		1.3
15-30 cm	$Ca(NO_3)_2$ (Inc.)		2.4
15-30 cm	$Ca(NO_3)_2$ (Surf.)		2.1
15-30 cm	Urea (Inc.)		1.3
15-30 cm	Urea (Surf.)		2.7
30-60 cm	Zero-N (Inc.)		1.4
30-60 cm	Zero-N (Surf.)		1.2
30-60 cm	$Ca(NO_3)_2$ (Inc.)		1.2
30-60 cm	$Ca(NO_3)_2$ (Surf.)		1.2
30-60 cm	Urea (Inc.)		1.4
30-60 cm	Urea (Surf.)		1.6
			NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
12 OCT 82			
all	Zero-N (Inc.)	2.8	0.5
all	Zero-N (Surf.)	3.4	0.9
all	$Ca(NO_3)_2$ (Inc.)	5.6	0.4
all	$Ca(NO_3)_2$ (Surf.)	4.4	1.2
all	Urea (Inc.)	4.0	1.4
all	Urea (Surf.)	5.6	1.0
		NS *	NS
0-15 cm	all	10.1	1.2
15-30 cm	all	4.5	0.7
30-60 cm	all	1.6	1.2
60-90 cm	all	1.4	0.4
90+ cm	all	3.6	0.9
		NS	NS
0-15 cm	Zero-N (Inc.)	2.0	0.6
0-15 cm	Zero-N (Surf.)	7.3	0.4
0-15 cm	$Ca(NO_3)_2$ (Inc.)	15.1	0.4
0-15 cm	$Ca(NO_3)_2$ (Surf.)	8.5	2.6
0-15 cm	Urea (Inc.)	9.2	2.3
0-15 cm	Urea (Surf.)	13.2	0.7
15-30 cm	Zero-N (Inc.)	4.7	0.2
15-30 cm	Zero-N (Surf.)	4.6	0.4
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.9	0.3
15-30 cm	$Ca(NO_3)_2$ (Surf.)	6.6	1.5
15-30 cm	Urea (Inc.)	3.6	1.5
15-30 cm	Urea (Surf.)	5.9	0.6
30-60 cm	Zero-N (Inc.)	2.2	0.7
30-60 cm	Zero-N (Surf.)	1.2	2.1
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.3	0.4
30-60 cm	$Ca(NO_3)_2$ (Surf.)	2.4	0.5
30-60 cm	Urea (Inc.)	1.5	1.5
30-60 cm	Urea (Surf.)	1.7	1.5
60-90 cm	Zero-N (Inc.)	1.0	0.3
60-90 cm	Zero-N (Surf.)	1.5	0.5
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.1	0.3
60-90 cm	$Ca(NO_3)_2$ (Surf.)	1.9	0.3
60-90 cm	Urea (Inc.)	1.6	0.5
60-90 cm	Urea (Surf.)	2.1	0.6
90+ cm	Zero-N (Inc.)	5.1	0.7
90+ cm	Zero-N (Surf.)	0.2	0.4
90+ cm	$Ca(NO_3)_2$ (Inc.)		
90+ cm	$Ca(NO_3)_2$ (Surf.)	2.9	0.4
90+ cm	Urea (Inc.)	4.3	0.6
90+ cm	Urea (Surf.)	4.7	1.6
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
19 MAY 83			
all	Zero-N (Inc.)	1.9	1.8 a *
all	Zero-N (Surf.)	1.8	2.3 a
all	$Ca(NO_3)_2$ (Inc.)	3.1	3.1 ab
all	$Ca(NO_3)_2$ (Surf.)	2.6	4.1 b
all	Urea (Inc.)	1.8	2.0 a
all	Urea (Surf.)	1.7	2.2 a
	BLSD	INT	1.7
0-15 cm	all	5.6	6.4 c
15-30 cm	all	1.5	1.6 b
30-60 cm	all	0.7	1.1 ab
60-90 cm	all	0.8	0.8 ab
90+ cm	all	0.7	0.6 a
	BLSD	INT	0.9
0-15 cm	Zero-N (Inc.)	4.8 c	4.4
0-15 cm	Zero-N (Surf.)	4.6 c	5.7
0-15 cm	$Ca(NO_3)_2$ (Inc.)	8.5 e	8.0
0-15 cm	$Ca(NO_3)_2$ (Surf.)	6.8 d	9.3
0-15 cm	Urea (Inc.)	4.4 c	5.0
0-15 cm	Urea (Surf.)	4.4 c	5.8
15-30 cm	Zero-N (Inc.)	1.6 ab	1.6
15-30 cm	Zero-N (Surf.)	1.4 ab	1.4
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.5 ab	1.3
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.7 b	2.5
15-30 cm	Urea (Inc.)	1.4 ab	1.4
15-30 cm	Urea (Surf.)	1.4 ab	1.6
30-60 cm	Zero-N (Inc.)	0.6 ab	0.7
30-60 cm	Zero-N (Surf.)	0.6 ab	0.7
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.8 ab	0.7
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.8 ab	2.7
30-60 cm	Urea (Inc.)	0.5 a	0.8
30-60 cm	Urea (Surf.)	0.8 ab	1.2
60-90 cm	Zero-N (Inc.)	0.8 ab	0.6
60-90 cm	Zero-N (Surf.)	0.7 ab	0.5
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.5 a	0.7
60-90 cm	$Ca(NO_3)_2$ (Surf.)	1.2 ab	1.3
60-90 cm	Urea (Inc.)	0.8 ab	0.7
60-90 cm	Urea (Surf.)	0.7 ab	1.0
90+ cm	Zero-N (Inc.)		
90+ cm	Zero-N (Surf.)		
90+ cm	$Ca(NO_3)_2$ (Inc.)		
90+ cm	$Ca(NO_3)_2$ (Surf.)		
90+ cm	Urea (Inc.)		
90+ cm	Urea (Surf.)	0.7 ab	0.6
	BLSD	1.2	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
01 JUN 83			
all	Zero-N (Inc.)	1.6	2.0
all	Zero-N (Surf.)	1.7	2.8
all	$Ca(NO_3)_2$ (Inc.)	4.8	20.1
all	$Ca(NO_3)_2$ (Surf.)	3.4	25.4
all	Urea (Inc.)	20.2	6.8
all	Urea (Surf.)	12.6	3.7
		INT *	INT
0-15 cm	all	17.6	18.9
15-30 cm	all	1.8	4.4
30-60 cm	all	1.7	7.1
		INT	INT
0-15 cm	Zero-N (Inc.)	3.2 ab	4.0 abc
0-15 cm	Zero-N (Surf.)	2.7 ab	4.8 abc
0-15 cm	$Ca(NO_3)_2$ (Inc.)	12.2 b	52.6 e
0-15 cm	$Ca(NO_3)_2$ (Surf.)	6.8 a	36.9 d
0-15 cm	Urea (Inc.)	52.4 d	14.6 c
0-15 cm	Urea (Surf.)	28.2 c	7.5 abc
15-30 cm	Zero-N (Inc.)	0.9 a	1.1 a
15-30 cm	Zero-N (Surf.)	1.3 ab	1.5 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.2 a	5.8 abc
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.5 ab	12.4 bc
15-30 cm	Urea (Inc.)	2.0 ab	2.4 ab
15-30 cm	Urea (Surf.)	4.6 ab	2.2 ab
30-60 cm	Zero-N (Inc.)	0.6 a	0.8 a
30-60 cm	Zero-N (Surf.)	0.9 a	1.5 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	1.0 a	8.4 abc
30-60 cm	$Ca(NO_3)_2$ (Surf.)	2.1 ab	26.8 d
30-60 cm	Urea (Inc.)	2.4 ab	2.5 ab
30-60 cm	Urea (Surf.)	3.3 ab	1.5 a
	BLSD	10.9	10.7

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
15 JUN 83			
all	Zero-N (Inc.)	0.8	1.4
all	Zero-N (Surf.)	0.7	1.2
all	$Ca(NO_3)_2$ (Inc.)	1.5	11.4
all	$Ca(NO_3)_2$ (Surf.)	2.0	16.3
all	Urea (Inc.)	4.1	6.4
all	Urea (Surf.)	10.8	4.1
		INT *	INT
0-15 cm	all	13.2	24.9
15-30 cm	all	0.6	2.3
30-60 cm	all	0.4	1.6
60-90 cm	all	0.4	0.9
90+ cm	all	0.5	0.8
		INT	INT
0-15 cm	Zero-N (Inc.)	2.4 ab	3.7 a
0-15 cm	Zero-N (Surf.)	2.4 ab	3.3 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	5.6 ab	45.6 d
0-15 cm	$Ca(NO_3)_2$ (Surf.)	6.6 b	58.6 e
0-15 cm	Urea (Inc.)	17.3 c	25.0 c
0-15 cm	Urea (Surf.)	45.0 d	13.3 d
15-30 cm	Zero-N (Inc.)	0.4 ab	0.9 a
15-30 cm	Zero-N (Surf.)	0.4 ab	1.0 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.4 ab	3.8 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.4 ab	3.6 a
15-30 cm	Urea (Inc.)	0.5 ab	1.5 a
15-30 cm	Urea (Surf.)	1.6 ab	2.7 a
30-60 cm	Zero-N (Inc.)	0.2 ab	0.7 a
30-60 cm	Zero-N (Surf.)	0.1 ab	0.8 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2 ab	3.2 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.5 ab	1.9 a
30-60 cm	Urea (Inc.)	0.5 ab	1.6 a
30-60 cm	Urea (Surf.)	0.8 ab	1.0 a
60-90 cm	Zero-N (Inc.)	0.1 ab	0.4 a
60-90 cm	Zero-N (Surf.)	0.1 ab	0.4 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2 ab	1.8 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.4 ab	1.4 a
60-90 cm	Urea (Inc.)	0.3 ab	0.9 a
60-90 cm	Urea (Surf.)	1.2 ab	0.6 a
90+ cm	Zero-N (Inc.)	0.0 a	0.2 a
90+ cm	Zero-N (Surf.)	0.0 a	0.4 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.0 a	1.2 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.0 a	0.7 a
90+ cm	Urea (Inc.)	0.3 ab	0.9 a
90+ cm	Urea (Surf.)	1.7 ab	1.0 a
	BLSD	6.6	9.2

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
28 JUN 83			
all	Zero-N (Inc.)	0.9	1.2
all	Zero-N (Surf.)	0.8	1.0
all	$Ca(NO_3)_2$ (Inc.)	1.6	13.0
all	$Ca(NO_3)_2$ (Surf.)	2.1	23.2
all	Urea (Inc.)	4.0	8.1
all	Urea (Surf.)	16.1	4.7
		INT *	INT
0-15 cm	all	8.8	15.3
15-30 cm	all	2.4	6.5
30-60 cm	all	1.1	3.4
		INT	INT
0-15 cm	Zero-N (Inc.)	1.6 a	1.3 a
0-15 cm	Zero-N (Surf.)	1.2 a	1.2 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.5 a	23.7 c
0-15 cm	$Ca(NO_3)_2$ (Surf.)	4.1 a	38.7 d
0-15 cm	Urea (Inc.)	9.4 b	18.1 c
0-15 cm	Urea (Surf.)	32.8 c	8.9 b
15-30 cm	Zero-N (Inc.)	0.6 a	1.3 a
15-30 cm	Zero-N (Surf.)	0.8 a	1.0 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.7 a	8.8 b
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.0 a	20.2 c
15-30 cm	Urea (Inc.)	1.6 a	3.8 ab
15-30 cm	Urea (Surf.)	9.2 b	2.8 ab
30-60 cm	Zero-N (Inc.)	0.4 a	1.1 a
30-60 cm	Zero-N (Surf.)	0.4 a	0.8 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.5 a	6.6 ab
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.8 a	7.4 ab
30-60 cm	Urea (Inc.)	1.1 a	2.5 ab
30-60 cm	Urea (Surf.)	3.8 ab	2.6 ab
	BLSD	5.7	7.1

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
13 JUL 83			
all	Zero-N (Inc.)	1.0	0.5
all	Zero-N (Surf.)	1.0	0.6
all	$Ca(NO_3)_2$ (Inc.)	1.9	2.5
all	$Ca(NO_3)_2$ (Surf.)	2.4	6.9
all	Urea (Inc.)	1.6	2.2
all	Urea (Surf.)	12.0	1.2
		INT *	INT
0-15 cm	all	15.0	7.2
15-30 cm	all	0.7	1.0
30-60 cm	all	0.4	0.8
60-90 cm	all	0.3	0.5
90+ cm	all	0.4	0.4
		INT	INT
0-15 cm	Zero-N (Inc.)	2.8 a	0.6 a
0-15 cm	Zero-N (Surf.)	2.4 a	0.6 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	7.1 a	7.0 b
0-15 cm	$Ca(NO_3)_2$ (Surf.)	8.8 a	24.7 c
0-15 cm	Urea (Inc.)	8.3 a	7.1 b
0-15 cm	Urea (Surf.)	55.9 b	3.3 ab
15-30 cm	Zero-N (Inc.)	0.6 a	0.4 a
15-30 cm	Zero-N (Surf.)	0.6 a	0.5 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.9 a	1.2 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.8 a	2.4 ab
15-30 cm	Urea (Inc.)	0.6 a	1.3 a
15-30 cm	Urea (Surf.)	0.8 a	0.6 a
30-60 cm	Zero-N (Inc.)	0.5 a	0.8 a
30-60 cm	Zero-N (Surf.)	0.4 a	0.8 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	0.7 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	1.0 a
30-60 cm	Urea (Inc.)	0.2 a	0.8 a
30-60 cm	Urea (Surf.)	0.4 a	0.7 a
60-90 cm	Zero-N (Inc.)	0.3 a	0.4 a
60-90 cm	Zero-N (Surf.)	0.5 a	0.5 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2 a	0.6 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.2 a	0.6 a
60-90 cm	Urea (Inc.)	0.2 a	0.5 a
60-90 cm	Urea (Surf.)	0.6 a	0.4 a
90+ cm	Zero-N (Inc.)	0.3 a	0.2 a
90+ cm	Zero-N (Surf.)	0.8 a	0.3 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.5 a	0.7 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	0.2 a
90+ cm	Urea (Inc.)	0.5 a	0.4 a
90+ cm	Urea (Surf.)	0.1 a	0.4 a
	BLSD	12.1	5.2

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
27 JUL 83			
all	Zero-N (Inc.)	2.1 a *	1.0
all	Zero-N (Surf.)	2.2 a	0.7
all	$Ca(NO_3)_2$ (Inc.)	3.7 ab	2.1
all	$Ca(NO_3)_2$ (Surf.)	4.2 b	3.5
all	Urea (Inc.)	2.6 ab	1.4
all	Urea (Surf.)	3.0 ab	1.3
	BLSD	1.7	INT
0-15 cm	all	6.1 b	2.3
15-30 cm	all	1.8 a	1.7
30-60 cm	all	0.9 a	1.0
	BLSD	1.4	INT
0-15 cm	Zero-N (Inc.)	4.3	1.8 abc
0-15 cm	Zero-N (Surf.)	4.1	0.8 ab
0-15 cm	$Ca(NO_3)_2$ (Inc.)	7.6	3.2 e
0-15 cm	$Ca(NO_3)_2$ (Surf.)	8.7	3.2 e
0-15 cm	Urea (Inc.)	5.2	2.2 cde
0-15 cm	Urea (Surf.)	7.1	2.5 de
15-30 cm	Zero-N (Inc.)	1.4	0.6 a
15-30 cm	Zero-N (Surf.)	1.7	0.6 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	2.2	1.9 bcd
15-30 cm	$Ca(NO_3)_2$ (Surf.)	2.5	5.3 f
15-30 cm	Urea (Inc.)	1.6	1.0 abc
15-30 cm	Urea (Surf.)	1.4	0.6 a
30-60 cm	Zero-N (Inc.)	0.7	0.6 a
30-60 cm	Zero-N (Surf.)	0.4	0.8 ab
30-60 cm	$Ca(NO_3)_2$ (Inc.)	1.2	1.1 abc
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.8	1.6 abcd
30-60 cm	Urea (Inc.)	1.1	1.0 abc
30-60 cm	Urea (Surf.)	1.3	0.6 ab
	BLSD	NS	1.3

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
10 AUG 83			
all	Zero-N (Inc.)	1.2	0.7
all	Zero-N (Surf.)	1.1	0.6
all	$Ca(NO_3)_2$ (Inc.)	1.0	0.7
all	$Ca(NO_3)_2$ (Surf.)	1.3	1.0
all	Urea (Inc.)	1.0	0.8
all	Urea (Surf.)	1.6	0.7
		NS *	NS
0-15 cm	all	3.9 b	1.0 b
15-30 cm	all	0.8 a	0.8 ab
30-60 cm	all	0.3 a	0.8 ab
60-90 cm	all	0.3 a	0.6 a
90+ cm	all	0.3 a	0.5 a
	BLSD	0.7	0.4
0-15 cm	Zero-N (Inc.)	3.4	1.0
0-15 cm	Zero-N (Surf.)	2.8	0.6
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.1	0.7
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.9	1.5
0-15 cm	Urea (Inc.)	3.5	1.4
0-15 cm	Urea (Surf.)	5.8	0.9
15-30 cm	Zero-N (Inc.)	0.7	0.4
15-30 cm	Zero-N (Surf.)	1.0	0.5
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.5	1.1
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.4	1.7
15-30 cm	Urea (Inc.)	0.8	0.6
15-30 cm	Urea (Surf.)	0.7	0.6
30-60 cm	Zero-N (Inc.)	0.5	0.7
30-60 cm	Zero-N (Surf.)	0.5	0.9
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.1	0.8
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4	0.9
30-60 cm	Urea (Inc.)	0.3	0.6
30-60 cm	Urea (Surf.)	0.2	0.6
60-90 cm	Zero-N (Inc.)	0.4	0.7
60-90 cm	Zero-N (Surf.)	0.2	0.6
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.5
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.3	0.6
60-90 cm	Urea (Inc.)	0.2	0.6
60-90 cm	Urea (Surf.)	0.4	0.5
90+ cm	Zero-N (Inc.)	0.1	0.4
90+ cm	Zero-N (Surf.)	0.1	0.4
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.5	0.3
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.2	0.4
90+ cm	Urea (Inc.)	0.3	0.7
90+ cm	Urea (Surf.)	0.3	0.6
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
23 AUG 83			
all	Zero-N (Inc.)	1.3	0.6 a *
all	Zero-N (Surf.)	1.7	0.6 a
all	$Ca(NO_3)_2$ (Inc.)	1.2	0.7 a
all	$Ca(NO_3)_2$ (Surf.)	1.4	1.4 b
all	Urea (Inc.)	1.4	0.6 a
all	Urea (Surf.)	1.9	0.7 a
	BLSD	INT	0.5
0-15 cm	all	3.1	0.6
15-30 cm	all	0.9	0.9
30-60 cm	all	0.4	0.7
		INT	NS
0-15 cm	Zero-N (Inc.)	2.7 cd	0.6
0-15 cm	Zero-N (Surf.)	2.8 d	0.4
0-15 cm	$Ca(NO_3)_2$ (Inc.)	2.5 bcd	0.5
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.5 bcd	0.7
0-15 cm	Urea (Inc.)	2.8 d	0.6
0-15 cm	Urea (Surf.)	5.1 e	1.0
15-30 cm	Zero-N (Inc.)	0.8 a	0.5
15-30 cm	Zero-N (Surf.)	1.6 abcd	0.5
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.9 ab	1.0
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.9 ab	2.4
15-30 cm	Urea (Inc.)	1.0 abc	0.5
15-30 cm	Urea (Surf.)	0.4 a	0.6
30-60 cm	Zero-N (Inc.)	0.4 a	0.6
30-60 cm	Zero-N (Surf.)	0.5 a	0.8
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.3 a	0.6
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.6 a	1.0
30-60 cm	Urea (Inc.)	0.2 a	0.7
30-60 cm	Urea (Surf.)	0.2 a	0.7
	BLSD	1.7	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
07 SEP 83			
all	Zero-N (Inc.)	0.8	0.6
all	Zero-N (Surf.)	0.8	0.5
all	$Ca(NO_3)_2$ (Inc.)	1.1	0.7
all	$Ca(NO_3)_2$ (Surf.)	1.0	0.7
all	Urea (Inc.)	0.9	0.6
all	Urea (Surf.)	1.0	0.6
		NS *	INT
0-15 cm	all	2.8 b	0.7
15-30 cm	all	0.6 a	0.5
30-60 cm	all	0.2 a	0.7
60-90 cm	all	0.2 a	0.6
90+ cm	all	0.3 a	0.5
	BLSD	0.6	INT
0-15 cm	Zero-N (Inc.)	2.2	0.8 cde
0-15 cm	Zero-N (Surf.)	2.3	0.5 abc
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.4	0.7 abcd
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.0	0.5 abc
0-15 cm	Urea (Inc.)	2.7	0.7 cde
0-15 cm	Urea (Surf.)	3.1	1.0 e
15-30 cm	Zero-N (Inc.)	0.4	0.4 ab
15-30 cm	Zero-N (Surf.)	0.8	0.4 ab
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.3	0.7 bcd
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.6	0.4 ab
15-30 cm	Urea (Inc.)	0.8	0.5 abc
15-30 cm	Urea (Surf.)	0.7	0.5 abc
30-60 cm	Zero-N (Inc.)	0.1	0.6 abc
30-60 cm	Zero-N (Surf.)	0.3	0.6 abcd
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.4	0.9 de
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.2	1.0 e
30-60 cm	Urea (Inc.)	0.3	0.5 abc
30-60 cm	Urea (Surf.)	0.1	0.5 abc
60-90 cm	Zero-N (Inc.)	0.3	0.6 abc
60-90 cm	Zero-N (Surf.)	0.2	0.5 abc
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.6 abc
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.2	0.6 abcd
60-90 cm	Urea (Inc.)	0.3	0.6 abc
60-90 cm	Urea (Surf.)	0.3	0.5 abc
90+ cm	Zero-N (Inc.)	0.4	0.5 abc
90+ cm	Zero-N (Surf.)	0.1	0.4 a
90+ cm	$Ca(NO_3)_2$ (Inc.)		
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.6	0.6 abc
90+ cm	Urea (Inc.)	0.3	0.5 abc
90+ cm	Urea (Surf.)	0.2	0.7 bcd
	BLSD	NS	0.3

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
22 SEP 83			
all	Zero-N (Inc.)	0.7	0.5 a *
all	Zero-N (Surf.)	0.7	0.5 a
all	$Ca(NO_3)_2$ (Inc.)	0.7	0.7 abc
all	$Ca(NO_3)_2$ (Surf.)	1.0	0.8 c
all	Urea (Inc.)	1.0	0.6 ab
all	Urea (Surf.)	1.1	0.7 bc
	BLSD	INT	0.2
0-15 cm	all	1.9	0.7 b
15-30 cm	all	0.4	0.5 a
30-60 cm	all	0.2	0.7 b
	BLSD	INT	0.2
0-15 cm	Zero-N (Inc.)	1.4 b	0.6
0-15 cm	Zero-N (Surf.)	1.4 b	0.6
0-15 cm	$Ca(NO_3)_2$ (Inc.)	1.5 bc	0.5
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.0 cd	0.6
0-15 cm	Urea (Inc.)	2.4 de	0.7
0-15 cm	Urea (Surf.)	2.6 e	1.0
15-30 cm	Zero-N (Inc.)	0.5 a	0.4
15-30 cm	Zero-N (Surf.)	0.3 a	0.4
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.5 a	0.6
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	0.8
15-30 cm	Urea (Inc.)	0.2 a	0.5
15-30 cm	Urea (Surf.)	0.4 a	0.4
30-60 cm	Zero-N (Inc.)	0.2 a	0.5
30-60 cm	Zero-N (Surf.)	0.1 a	0.5
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2 a	0.9
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	1.1
30-60 cm	Urea (Inc.)	0.3 a	0.7
30-60 cm	Urea (Surf.)	0.2 a	0.8
	BLSD	0.6	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
05 OCT 83			
all	Zero-N (Inc.)	0.6	0.6
all	Zero-N (Surf.)	1.3	0.9
all	$Ca(NO_3)_2$ (Inc.)	1.2	0.9
all	$Ca(NO_3)_2$ (Surf.)	1.2	0.8
all	Urea (Inc.)	1.1	0.7
all	Urea (Surf.)	1.2	0.8
		NS *	INT
0-15 cm	all	2.9 b	1.2
15-30 cm	all	0.7 a	0.6
30-60 cm	all	0.4 a	0.7
60-90 cm	all	0.5 a	0.6
90+ cm	all	0.5 a	0.8
	BLSD	0.5	INT
0-15 cm	Zero-N (Inc.)	1.6	0.9 abc
0-15 cm	Zero-N (Surf.)	2.5	0.8 ab
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.2	1.9 de
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.6	1.0 bc
0-15 cm	Urea (Inc.)	3.1	1.5 cd
0-15 cm	Urea (Surf.)	3.3	1.0 abc
15-30 cm	Zero-N (Inc.)	0.4	0.5 ab
15-30 cm	Zero-N (Surf.)	0.9	0.7 ab
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.5	0.5 ab
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.1	0.8 ab
15-30 cm	Urea (Inc.)	0.8	0.3 ab
15-30 cm	Urea (Surf.)	0.5	0.7 ab
30-60 cm	Zero-N (Inc.)	0.2	0.5 ab
30-60 cm	Zero-N (Surf.)	0.9	0.7 ab
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.7 ab
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.6	0.9 abc
30-60 cm	Urea (Inc.)	0.3	0.6 ab
30-60 cm	Urea (Surf.)	0.2	0.9 abc
60-90 cm	Zero-N (Inc.)	0.3	0.6 ab
60-90 cm	Zero-N (Surf.)	1.0	0.8 ab
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.3	0.4 ab
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.6	0.6 ab
60-90 cm	Urea (Inc.)	0.2	0.6 ab
60-90 cm	Urea (Surf.)	0.2	0.5 ab
90+ cm	Zero-N (Inc.)	0.5	0.6 ab
90+ cm	Zero-N (Surf.)	0.6	2.2 e
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.4	0.5 ab
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.3	0.3 a
90+ cm	Urea (Inc.)	0.2	0.5 ab
90+ cm	Urea (Surf.)	1.1	0.6 ab
	BLSD	NS	0.7

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
11 MAY 84			
all	Zero-N (Inc.)	1.0	0.4
all	Zero-N (Surf.)	1.4	0.8
all	$Ca(NO_3)_2$ (Inc.)	4.1	1.1
all	$Ca(NO_3)_2$ (Surf.)	1.7	1.2
all	Urea (Inc.)	1.0	1.1
all	Urea (Surf.)	1.5	1.4
		INT *	INT
0-15 cm	all	5.0	2.8
15-30 cm	all	0.9	0.4
30-60 cm	all	0.1	0.2
60-90 cm	all	0.3	0.3
90+ cm	all	0.0	0.0
		INT	INT
0-15 cm	Zero-N (Inc.)	2.8 a	1.2 c
0-15 cm	Zero-N (Surf.)	3.5 a	2.1 d
0-15 cm	$Ca(NO_3)_2$ (Inc.)	12.8 b	3.4 ef
0-15 cm	$Ca(NO_3)_2$ (Surf.)	4.0 a	2.6 de
0-15 cm	Urea (Inc.)	2.8 a	3.3 ef
0-15 cm	Urea (Surf.)	4.0 a	4.2 f
15-30 cm	Zero-N (Inc.)	0.0 a	0.1 ab
15-30 cm	Zero-N (Surf.)	1.6 a	0.3 ab
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.6 a	0.2 ab
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.5 a	1.0 bc
15-30 cm	Urea (Inc.)	0.2 a	0.3 ab
15-30 cm	Urea (Surf.)	1.2 a	0.3 ab
30-60 cm	Zero-N (Inc.)	0.1 a	0.2 ab
30-60 cm	Zero-N (Surf.)	0.1 a	0.2 ab
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2 a	0.2 ab
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.2 a	0.3 ab
30-60 cm	Urea (Inc.)	0.1 a	0.1 ab
30-60 cm	Urea (Surf.)	0.2 a	0.2 ab
60-90 cm	Zero-N (Inc.)	0.9 a	0.2 ab
60-90 cm	Zero-N (Surf.)	0.0 a	0.1 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	0.0 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	0.6 abc
60-90 cm	Urea (Inc.)	0.1 a	0.2 ab
60-90 cm	Urea (Surf.)	0.2 a	0.6 abc
90+ cm	Zero-N (Inc.)		
90+ cm	Zero-N (Surf.)	0.0 a	0.0 a
90+ cm	$Ca(NO_3)_2$ (Inc.)		
90+ cm	$Ca(NO_3)_2$ (Surf.)		
90+ cm	Urea (Inc.)		
90+ cm	Urea (Surf.)		
	BLSD	4.1	0.9

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
31 MAY 84			
all	Zero-N (Inc.)	3.0	1.7
all	Zero-N (Surf.)	2.7	1.8
all	$Ca(NO_3)_2$ (Inc.)	2.5	13.3
all	$Ca(NO_3)_2$ (Surf.)	2.5	18.0
all	Urea (Inc.)	15.5	5.5
all	Urea (Surf.)	11.5	4.8
		INT *	INT
0-15 cm	all	14.6	16.1
15-30 cm	all	2.0	2.3
30-60 cm	all	2.3	3.5
		INT	INT
0-15 cm	Zero-N (Inc.)	4.6 a	3.3 a
0-15 cm	Zero-N (Surf.)	4.2 a	3.5 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	6.1 a	28.2 c
0-15 cm	$Ca(NO_3)_2$ (Surf.)	5.1 a	34.4 d
0-15 cm	Urea (Inc.)	38.1 c	12.9 b
0-15 cm	Urea (Surf.)	30.8 b	11.7 b
15-30 cm	Zero-N (Inc.)	3.1 a	1.2 a
15-30 cm	Zero-N (Surf.)	1.9 a	1.0 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.3 a	4.8 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.6 a	3.9 a
15-30 cm	Urea (Inc.)	2.3 a	1.8 a
15-30 cm	Urea (Surf.)	3.4 a	1.6 a
30-60 cm	Zero-N (Inc.)	1.1 a	0.7 a
30-60 cm	Zero-N (Surf.)	2.1 a	1.2 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	1.1 a	3.3 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	1.9 a	12.8 b
30-60 cm	Urea (Inc.)	3.7 a	1.8 a
30-60 cm	Urea (Surf.)	4.1 a	1.1 a
	BLSD	6.2	5.8

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
13 JUN 84			
all	Zero-N (Inc.)	1.2	0.8
all	Zero-N (Surf.)	1.9	0.7
all	$Ca(NO_3)_2$ (Inc.)	2.5	15.3
all	$Ca(NO_3)_2$ (Surf.)	2.3	10.9
all	Urea (Inc.)	5.2	3.6
all	Urea (Surf.)	2.9	3.5
		INT *	INT
0-15 cm	all	8.7	24.0
15-30 cm	all	1.0	1.1
30-60 cm	all	1.0	0.8
60-90 cm	all	1.0	0.6
90+ cm	all	0.5	0.3
		INT	INT
0-15 cm	Zero-N (Inc.)	2.6 a	2.2 a
0-15 cm	Zero-N (Surf.)	2.1 a	1.5 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	8.0 c	59.2 d
0-15 cm	$Ca(NO_3)_2$ (Surf.)	7.2 bc	40.6 c
0-15 cm	Urea (Inc.)	20.7 d	16.8 b
0-15 cm	Urea (Surf.)	10.5 c	13.6 b
15-30 cm	Zero-N (Inc.)	0.6 a	0.8 a
15-30 cm	Zero-N (Surf.)	1.1 a	0.6 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	0.8 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.4 a	2.0 a
15-30 cm	Urea (Inc.)	0.6 a	1.0 a
15-30 cm	Urea (Surf.)	1.7 a	1.3 a
30-60 cm	Zero-N (Inc.)	0.8 a	0.5 a
30-60 cm	Zero-N (Surf.)	2.6 ab	0.6 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.7 a	0.6 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	1.7 a
30-60 cm	Urea (Inc.)	0.4 a	0.8 a
30-60 cm	Urea (Surf.)	0.7 a	0.6 a
60-90 cm	Zero-N (Inc.)	1.2 a	0.2 a
60-90 cm	Zero-N (Surf.)	2.3 a	0.4 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2 a	0.5 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.3 a	1.8 a
60-90 cm	Urea (Inc.)	0.2 a	0.3 a
60-90 cm	Urea (Surf.)	1.6 a	0.4 a
90+ cm	Zero-N (Inc.)	0.2 a	0.1 a
90+ cm	Zero-N (Surf.)	0.0 a	0.2 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.0 a	0.3 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	2.3 a	0.2 a
90+ cm	Urea (Inc.)	0.5 a	0.4 a
90+ cm	Urea (Surf.)	0.2 a	0.4 a
	BLSD	4.7	5.7

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
28 JUN 84			
all	Zero-N (Inc.)	2.7	0.4
all	Zero-N (Surf.)	2.4	0.6
all	$Ca(NO_3)_2$ (Inc.)	4.0	8.9
all	$Ca(NO_3)_2$ (Surf.)	5.3	12.0
all	Urea (Inc.)	3.7	4.4
all	Urea (Surf.)	16.1	6.8
		INT *	INT
0-15 cm	all	12.9	13.8
15-30 cm	all	2.4	1.8
30-60 cm	all	1.9	1.0
		INT	INT
0-15 cm	Zero-N (Inc.)	5.6 cde	0.5 a
0-15 cm	Zero-N (Surf.)	5.5 bcde	0.7 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	8.7 de	23.1 bc
0-15 cm	$Ca(NO_3)_2$ (Surf.)	9.2 e	27.8 c
0-15 cm	Urea (Inc.)	8.9 d	11.5 ab
0-15 cm	Urea (Surf.)	38.8 f	16.4 b
15-30 cm	Zero-N (Inc.)	1.8 abc	0.5 a
15-30 cm	Zero-N (Surf.)	0.7 ab	0.6 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	2.2 abc	1.8 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	3.4 abc	3.1 a
15-30 cm	Urea (Inc.)	1.6 abc	1.7 a
15-30 cm	Urea (Surf.)	4.1 abcd	3.0 a
30-60 cm	Zero-N (Inc.)	0.3 a	0.3 a
30-60 cm	Zero-N (Surf.)	0.4 a	0.5 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	1.7 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	3.2 abc	1.2 a
30-60 cm	Urea (Inc.)	0.7 ab	1.0 a
30-60 cm	Urea (Surf.)	5.3 bcde	1.1 a
	BLSD	4.9	12.6

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
12 JUL 84			
all	Zero-N (Inc.)	1.2	0.8
all	Zero-N (Surf.)	1.1	0.8
all	$Ca(NO_3)_2$ (Inc.)	1.6	1.4
all	$Ca(NO_3)_2$ (Surf.)	2.0	1.6
all	Urea (Inc.)	1.9	1.3
all	Urea (Surf.)	2.8	1.5
		INT *	INT
0-15 cm	all	5.8	1.8
15-30 cm	all	1.0	1.6
30-60 cm	all	0.5	1.0
60-90 cm	all	0.5	0.8
90+ cm	all	0.6	0.8
		INT	INT
0-15 cm	Zero-N (Inc.)	3.4 b	0.8 ab
0-15 cm	Zero-N (Surf.)	3.1 b	0.6 ab
0-15 cm	$Ca(NO_3)_2$ (Inc.)	5.4 c	2.1 bc
0-15 cm	$Ca(NO_3)_2$ (Surf.)	5.7 c	1.5 ab
0-15 cm	Urea (Inc.)	6.5 c	2.2 bc
0-15 cm	Urea (Surf.)	10.4 d	3.8 d
15-30 cm	Zero-N (Inc.)	0.8 a	0.4 a
15-30 cm	Zero-N (Surf.)	0.7 a	0.4 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.9 a	2.1 bc
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.4 a	3.3 cd
15-30 cm	Urea (Inc.)	1.3 a	2.0 abc
15-30 cm	Urea (Surf.)	1.1 a	1.0 ab
30-60 cm	Zero-N (Inc.)	0.2 a	0.9 ab
30-60 cm	Zero-N (Surf.)	0.5 a	1.0 ab
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	1.0 ab
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.8 a	1.3 ab
30-60 cm	Urea (Inc.)	0.4 a	1.0 ab
30-60 cm	Urea (Surf.)	0.2 a	0.9 ab
60-90 cm	Zero-N (Inc.)	0.5 a	0.8 ab
60-90 cm	Zero-N (Surf.)	0.4 a	0.9 ab
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	1.0 ab
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.5 a	0.6 ab
60-90 cm	Urea (Inc.)	0.5 a	0.6 ab
60-90 cm	Urea (Surf.)	0.6 a	0.8 ab
90+ cm	Zero-N (Inc.)	0.5 a	0.8 ab
90+ cm	Zero-N (Surf.)	0.2 a	0.9 ab
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.5 a	0.8 ab
90+ cm	$Ca(NO_3)_2$ (Surf.)	1.1 a	0.8 ab
90+ cm	Urea (Inc.)	0.5 a	0.6 ab
90+ cm	Urea (Surf.)	0.6 a	0.8 ab
	BLSD	1.4	1.6

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
25 JUL 84			
all	Zero-N (Inc.)	1.6	0.5
all	Zero-N (Surf.)	1.2	0.4
all	$Ca(NO_3)_2$ (Inc.)	1.6	1.2
all	$Ca(NO_3)_2$ (Surf.)	1.9	1.7
all	Urea (Inc.)	1.5	0.6
all	Urea (Surf.)	1.8	0.9
		NS *	INT
0-15 cm	all	3.5 b	0.7
15-30 cm	all	0.7 a	1.1
30-60 cm	all	0.4 a	0.8
	BLSD	0.7	INT
0-15 cm	Zero-N (Inc.)	3.3	0.4 a
0-15 cm	Zero-N (Surf.)	2.7	0.5 a
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.8	0.8 abc
0-15 cm	$Ca(NO_3)_2$ (Surf.)	4.0	0.8 abc
0-15 cm	Urea (Inc.)	3.3	0.6 ab
0-15 cm	Urea (Surf.)	3.8	1.3 bcd
15-30 cm	Zero-N (Inc.)	0.9	0.6 a
15-30 cm	Zero-N (Surf.)	0.4	0.4 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.6	1.9 d
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.7	2.7 e
15-30 cm	Urea (Inc.)	0.5	0.4 a
15-30 cm	Urea (Surf.)	1.2	0.5 a
30-60 cm	Zero-N (Inc.)	0.3	0.5 a
30-60 cm	Zero-N (Surf.)	0.2	0.4 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.5	1.0 abc
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4	1.4 cd
30-60 cm	Urea (Inc.)	0.6	0.6 ab
30-60 cm	Urea (Surf.)	0.5	0.8 abc
	BLSD	NS	0.7

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
08 AUG 84			
all	Zero-N (Inc.)	1.5	0.4
all	Zero-N (Surf.)	1.9	0.4
all	$Ca(NO_3)_2$ (Inc.)	2.1	0.8
all	$Ca(NO_3)_2$ (Surf.)	1.8	0.6
all	Urea (Inc.)	1.9	0.8
all	Urea (Surf.)	2.2	0.7
		INT *	INT
0-15 cm	all	4.4	0.7
15-30 cm	all	1.6	0.6
30-60 cm	all	1.1	0.7
60-90 cm	all	1.1	0.6
90+ cm	all	1.1	0.5
		INT	INT
0-15 cm	Zero-N (Inc.)	3.2 b	0.3 ab
0-15 cm	Zero-N (Surf.)	4.0 b	0.3 abcd
0-15 cm	$Ca(NO_3)_2$ (Inc.)	5.8 c	0.6 bcdefg
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.8 b	0.4 abcd
0-15 cm	Urea (Inc.)	3.7 b	1.3 i
0-15 cm	Urea (Surf.)	5.6 c	1.0 fghi
15-30 cm	Zero-N (Inc.)	1.6 a	0.3 ab
15-30 cm	Zero-N (Surf.)	1.6 a	0.2 ab
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.4 a	0.9 efghi
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.8 a	0.4 abcd
15-30 cm	Urea (Inc.)	1.8 a	1.1 ghi
15-30 cm	Urea (Surf.)	1.4 a	0.8 defgh
30-60 cm	Zero-N (Inc.)	0.8 a	0.4 abcd
30-60 cm	Zero-N (Surf.)	1.4 a	0.3 abcd
30-60 cm	$Ca(NO_3)_2$ (Inc.)	1.0 a	1.1 hi
30-60 cm	$Ca(NO_3)_2$ (Surf.)	1.2 a	1.0 ghi
30-60 cm	Urea (Inc.)	1.0 a	0.6 abcdef
30-60 cm	Urea (Surf.)	1.4 a	0.5 abcdef
60-90 cm	Zero-N (Inc.)	0.9 a	0.6 abcdef
60-90 cm	Zero-N (Surf.)	0.9 a	0.4 abcd
60-90 cm	$Ca(NO_3)_2$ (Inc.)	1.1 a	0.7 bcdefgh
60-90 cm	$Ca(NO_3)_2$ (Surf.)	1.1 a	0.6 abcdefg
60-90 cm	Urea (Inc.)	1.8 a	0.5 abcde
60-90 cm	Urea (Surf.)	1.0 a	0.4 abcd
90+ cm	Zero-N (Inc.)	0.8 a	0.4 abcd
90+ cm	Zero-N (Surf.)	1.6 a	0.8 cdefgh
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.8 a	0.2 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	1.1 a	0.3 abc
90+ cm	Urea (Inc.)	1.1 a	0.5 abcde
90+ cm	Urea (Surf.)	1.6 a	1.0 ghi
	BLSD	1.2	0.5

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
22 AUG 84			
all	Zero-N (Inc.)	1.4	0.4 a *
all	Zero-N (Surf.)	0.9	0.3 a
all	$Ca(NO_3)_2$ (Inc.)	1.7	0.6 a
all	$Ca(NO_3)_2$ (Surf.)	1.8	1.2 b
all	Urea (Inc.)	1.3	0.5 a
all	Urea (Surf.)	1.8	0.6 a
	BLSD	NS	0.6
0-15 cm	all	2.7 b	0.4
15-30 cm	all	1.0 a	0.7
30-60 cm	all	0.8 a	0.7
	BLSD	0.6	NS
0-15 cm	Zero-N (Inc.)	2.2	0.4
0-15 cm	Zero-N (Surf.)	1.8	0.3
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.4	0.4
0-15 cm	$Ca(NO_3)_2$ (Surf.)	2.9	0.3
0-15 cm	Urea (Inc.)	2.0	0.4
0-15 cm	Urea (Surf.)	3.6	0.6
15-30 cm	Zero-N (Inc.)	1.1	0.4
15-30 cm	Zero-N (Surf.)	0.4	0.3
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.1	0.5
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.2	2.0
15-30 cm	Urea (Inc.)	1.1	0.5
15-30 cm	Urea (Surf.)	0.9	0.5
30-60 cm	Zero-N (Inc.)	1.0	0.5
30-60 cm	Zero-N (Surf.)	0.5	0.4
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.4	0.8
30-60 cm	$Ca(NO_3)_2$ (Surf.)	1.3	1.2
30-60 cm	Urea (Inc.)	0.8	0.6
30-60 cm	Urea (Surf.)	0.8	0.6
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
05 SEP 84			
all	Zero-N (Inc.)	0.9	0.3
all	Zero-N (Surf.)	1.0	0.8
all	$Ca(NO_3)_2$ (Inc.)	1.1	0.7
all	$Ca(NO_3)_2$ (Surf.)	1.2	0.9
all	Urea (Inc.)	0.8	0.4
all	Urea (Surf.)	1.0	0.6
		INT *	INT
0-15 cm	all	3.3	0.8
15-30 cm	all	0.6	0.2
30-60 cm	all	0.2	0.6
60-90 cm	all	0.4	0.6
90+ cm	all	0.2	0.8
		INT	INT
0-15 cm	Zero-N (Inc.)	2.5 bc	0.4 abc
0-15 cm	Zero-N (Surf.)	3.5 cd	0.6 abcde
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.2 d	1.5 e
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.7 d	1.1 cde
0-15 cm	Urea (Inc.)	2.4 b	0.5 abcd
0-15 cm	Urea (Surf.)	3.7 d	1.0 abcde
15-30 cm	Zero-N (Inc.)	1.0 a	0.2 ab
15-30 cm	Zero-N (Surf.)	0.5 a	0.2 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	0.3 abc
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.7 a	0.4 abc
15-30 cm	Urea (Inc.)	0.6 a	0.2 abc
15-30 cm	Urea (Surf.)	0.3 a	0.2 a
30-60 cm	Zero-N (Inc.)	0.3 a	0.3 abc
30-60 cm	Zero-N (Surf.)	0.2 a	0.6 abcd
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2 a	0.6 abcd
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.4 a	1.1 bcde
30-60 cm	Urea (Inc.)	0.2 a	0.5 abcd
30-60 cm	Urea (Surf.)	0.2 a	0.8 abcde
60-90 cm	Zero-N (Inc.)	0.2 a	0.2 ab
60-90 cm	Zero-N (Surf.)	0.4 a	0.4 abc
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.4 a	0.5 abcd
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.3 a	1.4 de
60-90 cm	Urea (Inc.)	0.6 a	0.4 abc
60-90 cm	Urea (Surf.)	0.3 a	0.6 abcd
90+ cm	Zero-N (Inc.)	0.5 a	0.6 abcde
90+ cm	Zero-N (Surf.)	0.1 a	3.1 f
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.1 a	0.3 abc
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.3 a	0.4 abc
90+ cm	Urea (Inc.)	0.2 a	0.3 abc
90+ cm	Urea (Surf.)	0.2 a	0.4 abcd
	BLSD	1.0	0.9

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (μg/g)	NO_3^--N (μg/g)
18 SEP 84			
all	Zero-N (Inc.)	1.5	0.4 a *
all	Zero-N (Surf.)	1.5	0.3 a
all	$Ca(NO_3)_2$ (Inc.)	1.6	0.9 ab
all	$Ca(NO_3)_2$ (Surf.)	1.5	1.5 b
all	Urea (Inc.)	1.5	0.6 a
all	Urea (Surf.)	1.6	0.8 a
	BLSD	NS	0.7
0-15 cm	all	3.6 b	1.1 b
15-30 cm	all	0.6 a	0.3 a
30-60 cm	all	0.3 a	0.9 b
	BLSD	1.3	0.5
0-15 cm	Zero-N (Inc.)	3.0	0.7
0-15 cm	Zero-N (Surf.)	3.4	0.5
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.2	1.2
0-15 cm	$Ca(NO_3)_2$ (Surf.)	3.4	1.4
0-15 cm	Urea (Inc.)	3.2	1.2
0-15 cm	Urea (Surf.)	4.2	1.7
15-30 cm	Zero-N (Inc.)	1.1	0.2
15-30 cm	Zero-N (Surf.)	0.6	0.2
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.4	0.3
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.5	0.6
15-30 cm	Urea (Inc.)	0.9	0.2
15-30 cm	Urea (Surf.)	0.2	0.3
30-60 cm	Zero-N (Inc.)	0.3	0.3
30-60 cm	Zero-N (Surf.)	0.4	0.2
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.1	1.3
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.5	2.6
30-60 cm	Urea (Inc.)	0.5	0.4
30-60 cm	Urea (Surf.)	0.2	0.4
		NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
02 OCT 84			
all	Zero-N (Inc.)	0.8 ab *	0.4
all	Zero-N (Surf.)	1.3 b	1.0
all	$Ca(NO_3)_2$ (Inc.)	1.2 b	1.1
all	$Ca(NO_3)_2$ (Surf.)	2.1 c	2.0
all	Urea (Inc.)	0.5 a	0.9
all	Urea (Surf.)	0.8 ab	1.2
	BLSD	0.7	INT
0-15 cm	all	3.3 b	2.2
15-30 cm	all	0.8 a	0.8
30-60 cm	all	0.7 a	0.7
60-90 cm	all	0.3 a	0.6
90+ cm	all	0.2 a	1.0
	BLSD	1.0	INT
0-15 cm	Zero-N (Inc.)	2.7	0.8 ab
0-15 cm	Zero-N (Surf.)	3.6	1.1 abc
0-15 cm	$Ca(NO_3)_2$ (Inc.)	3.5	2.9 de
0-15 cm	$Ca(NO_3)_2$ (Surf.)	5.0	3.3 e
0-15 cm	Urea (Inc.)	1.9	2.3 bcde
0-15 cm	Urea (Surf.)	3.0	3.1 ef
15-30 cm	Zero-N (Inc.)	0.6	0.2 a
15-30 cm	Zero-N (Surf.)	0.6	0.3 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	1.3	0.5 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	1.4	2.4 cdef
15-30 cm	Urea (Inc.)	0.2	0.5 a
15-30 cm	Urea (Surf.)	0.5	0.8 ab
30-60 cm	Zero-N (Inc.)	0.0	0.2 a
30-60 cm	Zero-N (Surf.)	1.2	0.4 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.3	0.7 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	2.0	1.5 abcde
30-60 cm	Urea (Inc.)	0.1	0.4 a
30-60 cm	Urea (Surf.)	0.4	0.8 ab
60-90 cm	Zero-N (Inc.)	0.0	0.3 a
60-90 cm	Zero-N (Surf.)	0.5	0.5 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.5 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	0.6	1.4 abcd
60-90 cm	Urea (Inc.)	0.1	0.6 a
60-90 cm	Urea (Surf.)	0.2	0.4 a
90+ cm	Zero-N (Inc.)	0.2	0.3 a
90+ cm	Zero-N (Surf.)	0.1	5.0 g
90+ cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.5 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	0.1	0.3 a
90+ cm	Urea (Inc.)	0.1	0.3 a
90+ cm	Urea (Surf.)	0.2	0.7 ab
	BLSD	NS	1.6

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 18 Continued. Mean separations of available nitrogen in soil samples from main plots.

Soil Depth	Fert. Treatment	NH_4^+-N (µg/g)	NO_3^--N (µg/g)
20 MAY 85			
all	Zero-N (Inc.)	0.8 a *	0.4
all	Zero-N (Surf.)	0.8 a	0.8
all	$Ca(NO_3)_2$ (Inc.)	1.6 ab	1.1
all	$Ca(NO_3)_2$ (Surf.)	2.0 b	2.2
all	Urea (Inc.)	1.4 ab	1.3
all	Urea (Surf.)	1.1 ab	1.2
	BLSD	1.0	INT
0-15 cm	all	3.4 c	3.7
15-30 cm	all	0.5 a	0.6
30-60 cm	all	0.3 a	0.3
60-90 cm	all	0.6 a	0.2
90+ cm	all	1.3 b	0.3
	BLSD	0.6	INT
0-15 cm	Zero-N (Inc.)	2.4	1.7 cd
0-15 cm	Zero-N (Surf.)	2.1	2.4 d
0-15 cm	$Ca(NO_3)_2$ (Inc.)	4.7	3.8 e
0-15 cm	$Ca(NO_3)_2$ (Surf.)	4.3	5.2 f
0-15 cm	Urea (Inc.)	3.8	4.1 e
0-15 cm	Urea (Surf.)	3.2	4.4 e
15-30 cm	Zero-N (Inc.)	0.4	0.0 a
15-30 cm	Zero-N (Surf.)	0.1	0.1 a
15-30 cm	$Ca(NO_3)_2$ (Inc.)	0.4	0.3 a
15-30 cm	$Ca(NO_3)_2$ (Surf.)	0.8	1.7 cd
15-30 cm	Urea (Inc.)	0.4	0.8 ab
15-30 cm	Urea (Surf.)	0.7	0.4 a
30-60 cm	Zero-N (Inc.)	0.0	0.0 a
30-60 cm	Zero-N (Surf.)	0.4	0.0 a
30-60 cm	$Ca(NO_3)_2$ (Inc.)	0.2	0.0 a
30-60 cm	$Ca(NO_3)_2$ (Surf.)	0.8	1.4 bc
30-60 cm	Urea (Inc.)	0.4	0.4 a
30-60 cm	Urea (Surf.)	0.1	0.2 a
60-90 cm	Zero-N (Inc.)	0.2	0.1 a
60-90 cm	Zero-N (Surf.)	0.2	0.3 a
60-90 cm	$Ca(NO_3)_2$ (Inc.)	0.1	0.0 a
60-90 cm	$Ca(NO_3)_2$ (Surf.)	1.6	0.2 a
60-90 cm	Urea (Inc.)	0.5	0.2 a
60-90 cm	Urea (Surf.)	0.7	0.2 a
90+ cm	Zero-N (Inc.)	0.2	0.0 a
90+ cm	Zero-N (Surf.)	0.2	0.0 a
90+ cm	$Ca(NO_3)_2$ (Inc.)	2.1	0.0 a
90+ cm	$Ca(NO_3)_2$ (Surf.)	3.6	0.0 a
90+ cm	Urea (Inc.)	1.7	0.8 ab
90+ cm	Urea (Surf.)	1.5	0.5 a
	BLSD	NS	0.8

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 19. ANOVA tables of plant weight and nitrogen uptake from ^{15}N plots.

Source	df†	SS	MS	F
Plant N concentration (μg/g)				
1982				
Block (B)	4	1526413	381603	0.15
Fertilizer Treatment (F)	2	84384830	42192415	16.45 *
BxF (error)	6	15392301	2565384	
1983				
Block (B)	4	3009974	752493	0.30
Fertilizer Treatment (F)	2	23348163	11674081	4.71 *
BxF (error)	13	32213112	2477931	
1984				
Block (B)	4	1637195	409299	0.50
Fertilizer Treatment (F)	2	24387658	12193829	14.96 *
BxF (error)	6	4889620	814937	
Dry weight of plant material (kg/ha)				
1982				
Block (B)	4	3002308	150577	0.85
Fertilizer Treatment (F)	2	38973236	19486618	22.04 *
BxF (error)	6	5303902	883984	
1983				
Block (B)	4	4202425	1050606	0.57
Fertilizer Treatment (F)	2	69399272	34699636	18.74 *
BxF (error)	13	24069303	1851485	
1984				
Block (B)	4	10720231	2680058	2.46 *
Fertilizer Treatment (F)	2	73783929	36891965	33.76 *
BxF (error)	6	6538141	1089690	
Total nitrogen uptake by plants (kg/ha)				
1982				
Block (B)	4	305	76	2.07
Fertilizer Treatment (F)	2	10695	5348	145.06 *
BxF (error)	6	221	37	
1983				
Block (B)	4	704	176	0.69
Fertilizer Treatment (F)	2	7866	3933	15.45 *
BxF (error)	13	3308	254	
1984				
Block (B)	4	752	188	0.84
Fertilizer Treatment (F)	2	10409	5204	23.39 *
BxF (error)	6	1335	223	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 19 Continued. ANOVA tables of plant weight and nitrogen uptake from ^{15}N plots.

Source	df†	SS	MS	F
Atom % ^{15}N in total plant N				
1982				
Block (B)	4	0.17	0.04	2.90
Fertilizer Treatment (F)	2	20.32	10.16	699.04 *
BxF (error)	7	0.10	0.01	
1983				
Block (B)	4	1.09	0.27	3.44 *
Fertilizer Treatment (F)	2	18.43	9.22	116.60 *
BxF (error)	13	1.03	0.08	
1984				
Block (B)	4	0.00	0.00	0.01
Fertilizer Treatment (F)	2	18.26	9.13	259.11 *
BxF (error)	6	0.21	0.04	
Fertilizer N uptake by plants (kg/ha)				
1982				
Block (B)	4	248.2	62.1	1.92
Fertilizer Treatment (F)	1	152.3	152.3	9.10
BxF (error)	3	50.2	16.8	
1983				
Block (B)	4	322.1	80.5	0.76
Fertilizer Treatment (F)	1	0.0	0.0	0.00
BxF (error)	10	1065.0	106.5	
1984				
Block (B)	3	290.2	96.8	2.26
Fertilizer Treatment (F)	1	343.2	343.2	8.02
BxF (error)	3	128.4	42.8	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20. ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
NH_4^+-N concentration (µg/g)				
1982, 0-15 cm depth				
Block (B)	4	3273.7	818.4	4.43 *
Fertilizer Treatment (T)	2	1229.1	614.5	3.33
BxT (error 1)	8	1476.5	184.6	
Sampling Date (D)	4	11314.9	2828.7	11.87 *
BxD (error 2)	16	3812.5	238.3	
DxT	7	2663.2	380.4	3.40 *
BxDxT (error 3)	23	2574.1	111.9	
1982, 15-30 cm depth				
Block (B)	4	209.5	52.4	10.26 *
Fertilizer Treatment (T)	2	2.9	1.4	0.28
BxT (error 1)	8	40.8	5.1	
Sampling Date (D)	3	5164.2	1721.4	32.55 *
BxD (error 2)	12	634.6	52.9	
DxT	6	124.0	20.7	4.01 *
BxDxT (error 3)	19	98.1	5.2	
1982, 30-45 cm depth				
Block (B)	4	435.3	108.8	0.77
Fertilizer Treatment (T)	2	226.9	113.4	0.80
BxT (error 1)	8	1134.4	141.8	
Sampling Date (D)	3	2002.0	667.3	10.98 *
BxD (error 2)	12	729.6	60.8	
DxT	6	287.3	47.9	1.03
BxDxT (error 3)	20	933.3	46.7	
1983, 0-15 cm depth				
Block (B)	4	91.8	23.0	0.98
Fertilizer Treatment (T)	2	3555.1	1777.5	75.61 *
BxT (error 1)	8	188.1	23.5	
Sampling Date (D)	2	3947.8	1973.9	101.43 *
BxD (error 2)	8	155.7	19.5	
DxT	4	1837.9	459.5	13.94 *
BxDxT (error 3)	13	428.3	33.0	
1983, 15-30 cm depth				
Block (B)	4	2.7	0.7	1.43
Fertilizer Treatment (T)	2	0.8	0.4	0.83
BxT (error 1)	8	3.8	0.5	
Sampling Date (D)	2	26.4	13.2	9.72 *
BxD (error 2)	8	10.9	1.4	
DxT	4	3.5	0.9	1.53
BxDxT (error 3)	14	7.9	0.6	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 Continued. ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
NH_4^+-N concentration (μg/g)				
1983, 30-45 cm depth				
Block (B)	4	44.5	11.1	0.93
Fertilizer Treatment (T)	2	11.2	5.6	0.47
BxT (error 1)	8	95.5	11.9	
Sampling Date (D)	2	57.4	28.7	3.87
BxD (error 2)	8	59.3	7.4	
DxT	4	22.0	5.5	1.51
BxDxT (error 3)	14	51.0	3.6	
1984, 0-15 cm depth				
Block (B)	4	420.5	105.1	1.76
Fertilizer Treatment (T)	2	10250.5	5125.2	85.62 *
BxT (error 1)	8	478.9	59.9	
Sampling Date (D)	5	20522.8	4104.6	44.87 *
BxD (error 2)	20	1915.0	95.8	
DxT	10	16713.4	1671.3	19.21 *
BxDxT (error 3)	38	3306.6	87.0	
1984, 15-30 cm depth				
Block (B)	4	7.1	1.8	1.82
Fertilizer Treatment (T)	2	9.5	4.8	4.85 *
BxT (error 1)	8	7.8	1.0	
Sampling Date (D)	4	42.9	10.7	9.08 *
BxD (error 2)	16	18.9	1.2	
DxT	8	10.5	1.3	1.79
BxDxT (error 3)	30	22.1	0.7	
1984, 30-45 cm depth				
Block (B)	4	37.1	9.3	0.75
Fertilizer Treatment (T)	2	0.8	0.4	0.03
BxT (error 1)	8	98.9	12.4	
Sampling Date (D)	4	111.1	27.8	5.66 *
BxD (error 2)	16	78.5	4.9	
DxT	8	8.3	1.0	0.15
BxDxT (error 3)	29	199.9	6.9	
Atom % ^{15}N in NH_4^+ form				
1982, 0-15 cm depth				
Block (B)	4	2.48	0.62	3.10
Fertilizer Treatment (T)	2	0.24	0.12	0.60
BxT (error 1)	8	1.62	0.20	
Sampling Date (D)	4	67.20	16.80	29.47 *
BxD (error 2)	16	9.08	0.57	
DxT	6	1.27	0.21	1.03
BxDxT (error 3)	19	3.89	0.20	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 Continued. ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Atom % ^{15}N in NH_4^+ form				
1983, 0-15 cm depth				
Block (B)	4	0.03	0.01	0.08
Fertilizer Treatment (T)	2	12.10	6.05	55.00 *
BxT (error 1)	8	0.88	0.11	
Sampling Date (D)	2	45.70	22.85	16.21 *
BxD (error 2)	8	1.26	1.41	
DxT	3	8.32	2.77	27.70 *
BxDxT (error 3)	11	1.09	0.10	
1984, 0-15 cm depth				
Block (B)	4	0.49	0.12	0.21
Fertilizer Treatment (T)	2	44.13	22.06	39.39 *
BxT (error 1)	8	4.45	0.56	
Sampling Date (D)	5	52.01	10.40	24.76 *
BxD (error 2)	20	8.43	0.42	
DxT	9	32.79	3.64	11.72 *
BxDxT (error 3)	34	10.57	0.31	
NH_4^+-N from fertilizer source				
1982, 0-15 cm depth				
Block (B)	4	3960	990	5.14
Fertilizer Treatment (T)	1	168	168	0.87
BxT (error 1)	4	771	193	
Sampling Date (D)	4	20230	5058	10.75 *
BxD (error 2)	16	7530	471	
DxT	4	1250	313	2.96
BxDxT (error 3)	13	1372	106	
1983, 0-15 cm depth				
Block (B)	4	282	71	0.48
Fertilizer Treatment (T)	1	1454	1454	9.79 *
BxT (error 1)	4	594	148	
Sampling Date (D)	2	11725	5863	159.75 *
BxD (error 2)	8	294	37	
DxT	2	851	425	5.63 *
BxDxT (error 3)	8	604	75	
1984, 0-15 cm depth				
Block (B)	4	1698	425	1.86
Fertilizer Treatment (T)	1	2614	2614	11.46 *
BxT (error 1)	4	912	228	
Sampling Date (D)	5	47491	9498	44.14 *
BxD (error 2)	20	4303	215	
DxT	5	17782	3556	19.53 *
BxDxT (error 3)	20	3642	182	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 Continued. ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
NO_3^--N concentration (µg/g)				
1982, 0-15 cm depth				
Block (B)	4	141.6	35.4	0.54
Fertilizer Treatment (T)	2	882.4	441.2	6.72 *
BxT (error 1)	8	525.6	65.7	
Sampling Date (D)	4	3000.6	750.1	24.81 *
BxD (error 2)	16	483.8	30.2	
DxT	7	1188.6	169.8	0.64
BxDxT (error 3)	22	265.9	265.9	
1982, 15-30 cm depth				
Block (B)	4	81.3	20.3	0.50
Fertilizer Treatment (T)	2	156.9	78.4	1.93
BxT (error 1)	8	324.7	40.6	
Sampling Date (D)	3	712.5	237.5	17.07 *
BxD (error 2)	12	167.0	13.9	
DxT	6	464.9	77.5	3.88 *
BxDxT (error 3)	19	379.0	20.0	
1982, 30-45 cm depth				
Block (B)	4	9.2	2.2	1.17
Fertilizer Treatment (T)	2	7.6	3.8	2.01
BxT (error 1)	8	15.1	1.9	
Sampling Date (D)	3	46.8	15.6	9.64 *
BxD (error 2)	12	19.4	1.6	
DxT	6	50.2	8.4	5.56 *
BxDxT (error 3)	19	28.6	1.5	
1983, 0-15 cm depth				
Block (B)	4	64.1	16.0	4.55 *
Fertilizer Treatment (T)	2	45.4	22.7	6.45 *
BxT (error 1)	8	28.2	3.5	
Sampling Date (D)	2	121.5	60.8	10.01 *
BxD (error 2)	8	48.5	6.1	
DxT	4	42.7	10.7	4.06 *
BxDxT (error 3)	13	34.2	2.6	
1983, 15-30 cm depth				
Block (B)	4	9.2	2.3	0.60
Fertilizer Treatment (T)	2	6.9	3.5	0.91
BxT (error 1)	8	30.4	3.8	
Sampling Date (D)	2	33.5	16.8	5.62 *
BxD (error 2)	8	23.9	3.0	
DxT	4	22.8	5.7	1.72
BxDxT (error 3)	14	46.3	3.3	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 Continued. ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
NO_3^--N concentration (μg/g)				
1983, 30-45 cm depth				
Block (B)	4	440.0	109.9	1.15
Fertilizer Treatment (T)	2	199.0	99.5	1.04
BxT (error 1)	8	766.9	95.9	
Sampling Date (D)	2	5.9	3.0	3.52
BxD (error 2)	8	6.7	0.8	
DxT	4	2.6	0.6	0.35
BxDxT (error 3)	14	26.4	1.9	
1984, 0-15 cm depth				
Block (B)	4	46.2	11.5	0.86
Fertilizer Treatment (T)	2	518.4	259.2	19.30 *
BxT (error 1)	8	107.5	13.4	
Sampling Date (D)	5	1358.8	271.8	30.30 *
BxD (error 2)	20	179.4	9.0	
DxT	10	522.6	52.3	6.50 *
BxDxT (error 3)	38	305.4	8.0	
1984, 15-30 cm depth				
Block (B)	4	4.5	1.1	0.76
Fertilizer Treatment (T)	2	15.7	7.8	5.34 *
BxT (error 1)	8	11.7	1.5	
Sampling Date (D)	4	47.1	11.8	8.53 *
BxD (error 2)	16	22.1	1.4	
DxT	8	28.7	3.6	2.16
BxDxT (error 3)	30	49.7	1.7	
1984, 30-45 cm depth				
Block (B)	4	22.9	5.7	1.50
Fertilizer Treatment (T)	2	0.6	0.3	0.08
BxT (error 1)	8	30.5	3.8	
Sampling Date (D)	4	27.7	6.9	2.95
BxD (error 2)	16	37.5	2.4	
DxT	8	7.8	1.0	0.35
BxDxT (error 3)	29	79.8	2.8	
Atom % ^{15}N in NO_3^- form				
1982, 0-15 cm depth				
Block (B)	4	1.68	0.42	4.67 *
Fertilizer Treatment (T)	2	0.47	0.24	2.67
BxT (error 1)	8	0.74	0.09	
Sampling Date (D)	4	14.24	3.56	15.48 *
BxD (error 2)	16	3.61	0.23	
DxT	6	0.80	0.13	0.95
BxDxT (error 3)	19	2.65	0.14	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Atom % ^{15}N in NO_3^- form				
1983, 0-15 cm depth				
Block (B)	4	0.68	0.17	0.98
Fertilizer Treatment (T)	2	4.16	2.08	12.24 *
BxT (error 1)	8	1.38	0.17	
Sampling Date (D)	2	3.24	1.62	16.01 *
BxD (error 2)	8	0.81	0.10	
DxT	3	2.40	0.80	8.00 *
BxDxT (error 3)	11	1.10	0.10	
1984, 0-15 cm depth				
Block (B)	4	0.61	0.15	0.35
Fertilizer Treatment (T)	2	20.20	10.10	23.49 *
BxT (error 1)	8	3.46	0.43	
Sampling Date (D)	5	16.31	3.26	6.24 *
BxD (error 2)	20	10.46	0.52	
DxT	9	8.01	0.89	2.42 *
BxDxT (error 3)	33	12.14	0.37	
NO_3^--N from fertilizer source				
1982, 0-15 cm depth				
Block (B)	4	94.3	23.6	1.66
Fertilizer Treatment (T)	1	7.2	7.2	0.51
BxT (error 1)	4	56.7	14.2	
Sampling Date (D)	4	1425.6	356.4	13.31 *
BxD (error 2)	16	428.3	26.8	
DxT	4	74.7	18.7	1.07
BxDxT (error 3)	13	227.0	17.5	
1983, 0-15 cm depth				
Block (B)	4	32.2	8.0	4.96
Fertilizer Treatment (T)	1	8.6	8.6	5.30
BxT (error 1)	4	6.5	1.6	
Sampling Date (D)	2	72.6	36.3	5.99 *
BxD (error 2)	8	48.5	6.1	
DxT	2	6.3	3.2	1.65
BxDxT (error 3)	8	15.4	1.9	
1984, 0-15 cm depth				
Block (B)	4	30.8	7.7	0.65
Fertilizer Treatment (T)	1	28.5	28.5	2.41
BxT (error 1)	4	47.3	11.8	
Sampling Date (D)	5	667.2	133.4	9.62 *
BxD (error 2)	20	277.6	13.9	
DxT	5	122.4	24.5	2.06
BxDxT (error 3)	20	237.7	11.9	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Total N concentration (µg/g)				
1982, 0-15 cm depth				
Block (B)	4	3477865	869466	2.78
Fertilizer Treatment (T)	2	1417182	708591	2.27
BxT (error 1)	8	2497562	312195	
Sampling Date (D)	4	339046	84762	0.93
BxD (error 2)	16	1463523	91470	
DxT	7	541994	77428	0.44
BxDxT (error 3)	23	4054870	176299	
1982, 15-30 cm depth				
Block (B)	4	615241	153810	1.07
Fertilizer Treatment (T)	2	193736	96868	0.67
BxT (error 1)	8	1154837	144355	
Sampling Date (D)	3	3645189	1215063	19.67 *
BxD (error 2)	12	741267	61772	
DxT	6	367548	61258	0.89
BxDxT (error 3)	19	1308477	68867	
1982, 30-45 cm depth				
Block (B)	4	649167	162292	2.44
Fertilizer Treatment (T)	2	14235	7117	0.11
BxT (error 1)	8	532747	66593	
Sampling Date (D)	3	28966	9655	0.63
BxD (error 2)	12	185002	15417	
DxT	6	24631	4105	0.47
BxDxT (error 3)	19	165258	8698	
1983, 0-15 cm depth				
Block (B)	4	5047541	1261885	2.41
Fertilizer Treatment (T)	2	1811268	905634	1.73
BxT (error 1)	8	4187762	523470	
Sampling Date (D)	2	264508	132254	8.20 *
BxD (error 2)	8	129023	16128	
DxT	4	70326	17582	0.84
BxDxT (error 3)	13	272281	20945	
1983, 15-30 cm depth				
Block (B)	4	1239678	309920	1.74
Fertilizer Treatment (T)	2	630662	315331	1.77
BxT (error 1)	8	1421274	177659	
Sampling Date (D)	2	108844	54422	0.34
BxD (error 2)	8	1291775	161472	
DxT	4	283621	70905	0.64
BxDxT (error 3)	14	1539312	109951	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Total N concentration (μg/g)				
1983, 30-45 cm depth				
Block (B)	4	2849705	712426	1.21
Fertilizer Treatment (T)	2	1721040	860520	1.46
BxT (error 1)	8	4715403	589425	
Sampling Date (D)	2	286465	143233	1.55
BxD (error 2)	8	740057	92507	
DxT	4	203746	50937	0.51
BxDxT (error 3)	14	1385444	98960	
1984, 0-15 cm depth				
Block (B)	4	6080658	1520164	1.88
Fertilizer Treatment (T)	2	4601579	2300789	2.85
BxT (error 1)	8	6457147	807143	
Sampling Date (D)	5	13662	2732	0.05
BxD (error 2)	20	1022195	51110	
DxT	10	511216	51122	1.18
BxDxT (error 3)	36	1555991	43222	
1984, 15-30 cm depth				
Block (B)	4	1858134	464533	1.22
Fertilizer Treatment (T)	2	733922	366961	0.97
BxT (error 1)	8	3055131	381891	
Sampling Date (D)	4	2363981	590995	6.81 *
BxD (error 2)	16	1387825	86739	
DxT	8	662635	82829	0.90
BxDxT (error 3)	30	2767885	92263	
1984, 30-45 cm depth				
Block (B)	4	1015390	253848	0.82
Fertilizer Treatment (T)	2	525663	262831	0.85
BxT (error 1)	8	2466374	308297	
Sampling Date (D)	4	294433	73608	0.55
BxD (error 2)	16	2123776	132736	
DxT	8	1232391	154049	1.01
BxDxT (error 3)	28	4277301	152761	
Atom % ^{15}N in Total N				
1982, 0-15 cm depth				
Block (B)	4	0.0154	0.0039	1.36
Fertilizer Treatment (T)	2	0.0605	0.0303	10.73 *
BxT (error 1)	8	0.0226	0.0028	
Sampling Date (D)	4	0.0731	0.0183	6.32 *
BxD (error 2)	16	0.0463	0.0029	
DxT	7	0.0444	0.0063	3.33 *
BxDxT (error 3)	23	0.0438	0.0019	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Atom % ^{15}N in Total N				
1982, 15-30 cm depth				
Block (B)	4	0.0008	0.0002	0.57
Fertilizer Treatment (T)	2	0.0045	0.0023	6.23 *
BxT (error 1)	8	0.0029	0.0004	
Sampling Date (D)	3	0.0009	0.0003	1.86
BxD (error 2)	12	0.0020	0.0002	
DxT	6	0.0009	0.0001	1.03
BxDxT (error 3)	16	0.0022	0.0001	
1982, 30-45 cm depth				
Block (B)	4	0.0047	0.0012	1.47
Fertilizer Treatment (T)	2	0.0065	0.0033	4.10
BxT (error 1)	8	0.0064	0.0008	
Sampling Date (D)	3	0.0050	0.0017	3.02
BxD (error 2)	12	0.0067	0.0006	
DxT	6	0.0026	0.0004	0.69
BxDxT (error 3)	20	0.0127	0.0006	
1983, 0-15 cm depth				
Block (B)	4	0.0180	0.0045	0.87
Fertilizer Treatment (T)	2	0.1141	0.0571	11.06 *
BxT (error 1)	8	0.0413	0.0052	
Sampling Date (D)	2	0.0506	0.0253	22.58 *
BxD (error 2)	8	0.0090	0.0011	
DxT	4	0.0319	0.0080	4.15 *
BxDxT (error 3)	12	0.0231	0.0018	
1983, 15-30 cm depth				
Block (B)	4	0.0012	0.0003	0.69
Fertilizer Treatment (T)	2	0.0092	0.0046	10.61 *
BxT (error 1)	8	0.0035	0.0004	
Sampling Date (D)	2	0.0025	0.0013	3.60
BxD (error 2)	8	0.0028	0.0003	
DxT	4	0.0060	0.0015	2.93
BxDxT (error 3)	14	0.0072	0.0005	
1983, 30-45 cm depth				
Block (B)	4	0.0109	0.0027	2.02
Fertilizer Treatment (T)	2	0.0128	0.0064	4.76 *
BxT (error 1)	8	0.0107	0.0013	
Sampling Date (D)	2	0.0213	0.0106	5.58 *
BxD (error 2)	8	0.0151	0.0019	
DxT	4	0.0091	0.0023	1.89
BxDxT (error 3)	14	0.0169	0.0012	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Atom % ^{15}N in Total N				
1984, 0-15 cm depth				
Block (B)	4	0.0101	0.0025	1.00
Fertilizer Treatment (T)	2	0.2383	0.1192	47.23 *
BxT (error 1)	8	0.0202	0.0025	
Sampling Date (D)	5	0.2291	0.0458	17.10 *
BxD (error 2)	20	0.0536	0.0027	
DxT	10	0.1461	0.0146	8.47 *
BxDxT (error 3)	37	0.0638	0.0017	
1984, 15-30 cm depth				
Block (B)	4	0.0005	0.0001	0.75
Fertilizer Treatment (T)	2	0.0000	0.0000	0.06
BxT (error 1)	8	0.0014	0.0002	
Sampling Date (D)	4	0.0034	0.0009	21.30 *
BxD (error 2)	16	0.0006	0.0000	
DxT	8	0.0006	0.0001	0.86
BxDxT (error 3)	28	0.0023	0.0001	
1984, 30-45 cm depth				
Block (B)	4	0.0215	0.0054	0.73
Fertilizer Treatment (T)	2	0.0348	0.0174	2.38
BxT (error 1)	8	0.0585	0.0073	
Sampling Date (D)	4	0.0352	0.0088	2.77
BxD (error 2)	16	0.0509	0.0032	
DxT	8	0.0212	0.0026	0.45
BxDxT (error 3)	27	0.1606	0.0059	
Total N from fertilizer source				
1982, 0-15 cm depth				
Block (B)	4	13539.0	3384.7	1.55
Fertilizer Treatment (T)	1	330.4	330.4	0.15
BxT (error 1)	4	8736.0	2184.0	
Sampling Date (D)	4	45946.1	11486.5	7.66 *
BxD (error 2)	16	24000.3	1500.0	
DxT	4	11815.1	2953.8	2.92
BxDxT (error 3)	14	14166.6	1011.9	
1982, 15-30 cm depth				
Block (B)	4	305.9	76.5	1.29
Fertilizer Treatment (T)	1	24.4	24.4	0.41
BxT (error 1)	4	237.6	59.4	
Sampling Date (D)	3	211.7	70.6	1.39
BxD (error 2)	12	609.3	50.8	
DxT	3	132.0	44.0	3.19
BxDxT (error 3)	10	138.1	13.8	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Total N from fertilizer source				
1982, 30-45 cm depth				
Block (B)	4	258.2	64.6	1.82
Fertilizer Treatment (T)	1	42.5	42.5	1.20
BxT (error 1)	4	141.9	35.5	
Sampling Date (D)	3	137.4	45.8	1.68
BxD (error 2)	12	327.1	27.3	
DxT	3	3.6	1.2	0.08
BxDxT (error 3)	11	161.6	14.7	
1983, 0-15 cm depth				
Block (B)	4	2118.3	529.6	0.33
Fertilizer Treatment (T)	1	8968.9	8968.9	5.54
BxT (error 1)	4	6474.0	1618.5	
Sampling Date (D)	2	33722.4	16861.2	51.85 *
BxD (error 2)	8	2601.6	325.2	
DxT	2	5469.3	2734.6	7.76 *
BxDxT (error 3)	7	2467.6	352.5	
1983, 15-30 cm depth				
Block (B)	4	133.8	33.4	16.56 *
Fertilizer Treatment (T)	1	21.0	21.0	10.40 *
BxT (error 1)	4	8.1	2.0	
Sampling Date (D)	2	92.6	46.3	14.09 *
BxD (error 2)	8	26.3	3.3	
DxT	2	23.5	11.8	2.61
BxDxT (error 3)	7	31.5	4.5	
1983, 30-45 cm depth				
Block (B)	4	148.5	37.1	2.31
Fertilizer Treatment (T)	1	20.4	20.4	1.27
BxT (error 1)	4	64.2	16.0	
Sampling Date (D)	2	391.8	195.9	5.26 *
BxD (error 2)	8	298.2	37.3	
DxT	2	18.8	9.4	0.42
BxDxT (error 3)	7	157.9	22.6	
1984, 0-15 cm depth				
Block (B)	4	4078.0	1019.5	1.08
Fertilizer Treatment (T)	1	9594.5	9594.5	10.17 *
BxT (error 1)	4	3773.1	943.3	
Sampling Date (D)	5	112975.1	22595.0	19.07 *
BxD (error 2)	20	23699.6	1185.0	
DxT	5	16392.5	3278.5	6.28 *
BxDxT (error 3)	20	10442.2	522.1	

- Continued -

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 20 (Continued). ANOVA tables of soil nitrogen concentrations in ^{15}N plots.

Source	df†	SS	MS	F
Total N from fertilizer source				
1984, 15-30 cm depth				
Block (B)	4	26.5	6.6	0.30
Fertilizer Treatment (T)	1	22.6	22.6	1.02
BxT (error 1)	4	88.2	22.0	
Sampling Date (D)	4	376.3	94.1	9.30 *
BxD (error 2)	16	161.8	10.1	
DxT	4	86.4	21.6	1.11
BxDxT (error 3)	16	312.1	19.5	
1984, 30-45 cm depth				
Block (B)	4	125.3	31.3	0.45
Fertilizer Treatment (T)	1	35.3	35.3	0.51
BxT (error 1)	4	276.3	69.1	
Sampling Date (D)	4	356.3	89.1	2.72
BxD (error 2)	16	523.6	32.7	
DxT	4	39.9	10.0	0.16
BxDxT (error 3)	16	995.8	62.2	

* Significant at the 5% level of probability.
† df were corrected for missing data.

Table 21. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 NH_4^+-N Concentration (µg/g)				
all	Zero-N	17.2	11.3	11.0
all	Urea (Inc.)	29.4	10.9	7.9
all	Urea (Surf.)	31.1	12.0	8.9
		INT *	INT	NS
16 JUN 82	all	49.4		
23 JUN 82	all	24.0	1.6	4.6 a
02 AUG 82	all	2.2	0.7	0.9 a
26 AUG 82	all	35.2	24.2	13.8 b
28 SEP 82	all	28.8	18.3	17.3 b
	BLSD	INT	INT	6.3
16 JUN 82	Urea (Inc.)	54.0 e		
16 JUN 82	Urea (Surf.)	43.7 de		
23 JUN 82	Zero-N	4.3 a	1.2 a	2.5
23 JUN 82	Urea (Inc.)	24.8 bc	1.5 a	5.7
23 JUN 82	Urea (Surf.)	43.0 de	2.2 a	5.7
02 AUG 82	Zero-N	1.7 a	0.9 a	0.2
02 AUG 82	Urea (Inc.)	2.1 a	0.6 a	1.0
02 AUG 82	Urea (Surf.)	2.6 a	0.6 a	1.2
26 AUG 82	Zero-N	26.2 bc	27.3 d	15.0
26 AUG 82	Urea (Inc.)	42.3 de	22.8 c	12.7
26 AUG 82	Urea (Surf.)	37.6 cd	23.0 c	14.0
28 SEP 82	Zero-N	30.5 bcd	14.9 b	22.9
28 SEP 82	Urea (Inc.)	22.2 b	20.7 c	13.4
28 SEP 82	Urea (Surf.)	32.3 bcd	19.9 c	14.8
	BLSD	15.2	3.2	NS
1983 NH_4^+-N Concentration (µg/g)				
all	Zero-N	1.6	1.6	3.5
all	Urea (Inc.)	18.1	1.5	2.7
all	Urea (Surf.)	26.5	1.9	3.1
		INT	NS	NS
20 MAY 83	all	32.4	1.2 a	2.0
28 JUN 83	all	14.4	2.8 b	4.4
22 JUL 83	all	2.8	1.0 a	2.9
	BLSD	INT	1.0	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 NH_4^+-N Concentration (µg/g)				
20 MAY 83	Zero-N	2.2 a *	1.3	2.7
20 MAY 83	Urea (Inc.)	37.4 c	1.2	1.8
20 MAY 83	Urea (Surf.)	45.4 d	1.2	1.5
28 JUN 83	Zero-N	1.6 a	2.3	3.0
28 JUN 83	Urea (Inc.)	14.2 b	2.7	4.3
28 JUN 83	Urea (Surf.)	30.6 c	3.4	5.7
22 JUL 83	Zero-N	1.3 a	1.4	4.7
22 JUL 83	Urea (Inc.)	2.7 a	0.7	2.0
22 JUL 83	Urea (Surf.)	4.3 a	0.8	1.7
	BLSD	7.5	NS	NS
1984 NH_4^+-N Concentration (µg/g)				
all	Zero-N	4.3	1.0 a	1.6
all	Urea (Inc.)	19.7	1.6 ab	1.2
all	Urea (Surf.)	30.8	1.9 b	1.3
	BLSD	INT	0.7	NS
18 MAY 84	all	36.4		
31 MAY 84	all	45.6	2.4 b	3.4 c
28 JUN 84	all	12.3	2.6 b	0.8 ab
25 JUL 84	all	10.6	1.0 a	0.1 a
22 AUG 84	all	3.6	0.9 a	0.4 a
18 SEP 84	all	2.6	0.8 a	2.2 bc
	BLSD	INT	0.8	1.8
18 MAY 84	Zero-N	3.6 ab		
18 MAY 84	Urea (Inc.)	54.2 e		
18 MAY 84	Urea (Surf.)	51.5 e		
31 MAY 84	Zero-N	3.7 ab	1.1	4.3
31 MAY 84	Urea (Inc.)	34.2 d	3.4	3.1
31 MAY 84	Urea (Surf.)	90.6 f	3.0	2.8
28 JUN 84	Zero-N	7.3 ab	2.2	0.6
28 JUN 84	Urea (Inc.)	8.3 ab	2.4	0.5
28 JUN 84	Urea (Surf.)	21.2 c	3.0	1.4
25 JUL 84	Zero-N	7.1 ab	0.4	0.2
25 JUL 84	Urea (Inc.)	11.6 abc	1.4	0.2
25 JUL 84	Urea (Surf.)	13.1 bc	1.3	0.0
22 AUG 84	Zero-N	2.5 ab	0.6	0.6
22 AUG 84	Urea (Inc.)	3.5 ab	0.6	0.3
22 AUG 84	Urea (Surf.)	4.8 ab	1.5	0.2
18 SEP 84	Zero-N	1.6 a	0.9	2.5
18 SEP 84	Urea (Inc.)	3.0 ab	0.6	2.2
18 SEP 84	Urea (Surf.)	3.3 ab	0.9	1.9
	BLSD	10.7	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 Atom % ^{15}N in NH_4^+ form				
all	Zero-N	0.412		
all	Urea (Inc.)	1.654		
all	Urea (Surf.)	1.604		
		NS *		
16 JUN 82	all	3.603 c		
23 JUN 82	all	2.732 b		
02 AUG 82	all	0.761 a		
26 AUG 82	all	0.421 a		
28 SEP 82	all	0.457 a		
	BLSD	0.601		
16 JUN 82	Urea (Inc.)	3.660		
16 JUN 82	Urea (Surf.)	3.533		
23 JUN 82	Zero-N			
23 JUN 82	Urea (Inc.)	2.422		
23 JUN 82	Urea (Surf.)	3.042		
02 AUG 82	Zero-N	0.500		
02 AUG 82	Urea (Inc.)	0.951		
02 AUG 82	Urea (Surf.)	0.729		
26 AUG 82	Zero-N	0.393		
26 AUG 82	Urea (Inc.)	0.441		
26 AUG 82	Urea (Surf.)	0.432		
28 SEP 82	Zero-N	0.378		
28 SEP 82	Urea (Inc.)	0.585		
28 SEP 82	Urea (Surf.)	0.434		
		NS		
1983 Atom % ^{15}N in NH_4^+ form				
all	Zero-N	0.493		
all	Urea (Inc.)	2.449		
all	Urea (Surf.)	2.723		
		INT		
20 MAY 83	all	4.049		
28 JUN 83	all	2.028		
22 JUL 83	all	0.727		
		INT		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 Atom % ^{15}N in NH_4^+ form				
20 MAY 83	Zero-N			
20 MAY 83	Urea (Inc.)	3.745 e *		
20 MAY 83	Urea (Surf.)	4.354 f		
28 JUN 83	Zero-N	0.470 a		
28 JUN 83	Urea (Inc.)	2.585 c		
28 JUN 83	Urea (Surf.)	3.280 d		
22 JUL 83	Zero-N	0.517 a		
22 JUL 83	Urea (Inc.)	1.018 b		
22 JUL 83	Urea (Surf.)	0.647 ab		
	BLSD	0.400		
1984 Atom % ^{15}N in NH_4^+ form				
all	Zero-N	0.618		
all	Urea (Inc.)	1.781		
all	Urea (Surf.)	2.192		
		INT		
18 MAY 84	all	2.672		
31 MAY 84	all	2.617		
28 JUN 84	all	1.245		
25 JUL 84	all	0.809		
22 AUG 84	all	1.180		
18 SEP 84	all	0.775		
		INT		
18 MAY 84	Zero-N	0.569 a		
18 MAY 84	Urea (Inc.)	4.173 d		
18 MAY 84	Urea (Surf.)	3.274 c		
31 MAY 84	Zero-N	0.667 a		
31 MAY 84	Urea (Inc.)	2.665 bc		
31 MAY 84	Urea (Surf.)	4.129 d		
28 JUN 84	Zero-N	0.547 a		
28 JUN 84	Urea (Inc.)	1.094 a		
28 JUN 84	Urea (Surf.)	2.094 b		
25 JUL 84	Zero-N	0.752 a		
25 JUL 84	Urea (Inc.)	0.801 a		
25 JUL 84	Urea (Surf.)	0.874 a		
22 AUG 84	Zero-N	0.562 a		
22 AUG 84	Urea (Inc.)	0.946 a		
22 AUG 84	Urea (Surf.)	2.031 b		
18 SEP 84	Zero-N			
18 SEP 84	Urea (Inc.)	0.811 a		
18 SEP 84	Urea (Surf.)	0.746 a		
	BLSD	0.677		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 NH_4^+-N from fertilizer source (kg/ha)				
all	Urea (Inc.)	17.3		
all	Urea (Surf.)	18.3		
		NS *		
16 JUN 82	all	52.8 b		
23 JUN 82	all	34.2 b		
02 AUG 82	all	0.4 a		
26 AUG 82	all	0.8 a		
28 SEP 82	all	1.0 a		
	BLSD	19.8		
16 JUN 82	Urea (Inc.)	58.2		
16 JUN 82	Urea (Surf.)	46.0		
23 JUN 82	Urea (Inc.)	22.3		
23 JUN 82	Urea (Surf.)	46.0		
02 AUG 82	Urea (Inc.)	0.4		
02 AUG 82	Urea (Surf.)	0.3		
26 AUG 82	Urea (Inc.)	0.9		
26 AUG 82	Urea (Surf.)	0.7		
28 SEP 82	Urea (Inc.)	1.5		
28 SEP 82	Urea (Surf.)	0.6		
		NS		
1983 NH_4^+-N from fertilizer source (kg/ha)				
all	Urea (Inc.)	17.2		
all	Urea (Surf.)	31.1		
		INT		
20 MAY 83	all	49.1		
28 JUN 83	all	22.6		
22 JUL 83	all	0.7		
		INT		
20 MAY 83	Urea (Inc.)	40.2 b		
20 MAY 83	Urea (Surf.)	57.9 c		
28 JUN 83	Urea (Inc.)	10.2 a		
28 JUN 83	Urea (Surf.)	34.9 b		
22 JUL 83	Urea (Inc.)	1.0 a		
22 JUL 83	Urea (Surf.)	0.4 a		
	BLSD	11.7		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1984 NH_4^+-N from fertilizer source (kg/ha)				
all	Urea (Inc.)	15.9		
all	Urea (Surf.)	29.1		
		INT *		
18 MAY 84	all	55.6		
31 MAY 84	all	68.1		
28 JUN 84	all	7.5		
25 JUL 84	all	1.8		
22 AUG 84	all	1.6		
18 SEP 84	all	0.4		
		INT		
18 MAY 84	Urea (Inc.)	65.9 d		
18 MAY 84	Urea (Surf.)	45.2 c		
31 MAY 84	Urea (Inc.)	24.4 b		
31 MAY 84	Urea (Surf.)	111.8 e		
28 JUN 84	Urea (Inc.)	2.3 a		
28 JUN 84	Urea (Surf.)	12.8 ab		
25 JUL 84	Urea (Inc.)	1.6 a		
25 JUL 84	Urea (Surf.)	2.1 a		
22 AUG 84	Urea (Inc.)	0.8 a		
22 AUG 84	Urea (Surf.)	2.4 a		
18 SEP 84	Urea (Inc.)	0.4 a		
18 SEP 84	Urea (Surf.)	0.4 a		
	BLSD	16.4		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 NO_3^--N Concentration (μg/g)				
all	Zero-N	1.8	2.9	1.7
all	Urea (Inc.)	8.9	3.2	2.1
all	Urea (Surf.)	12.5	7.3	2.9
		INT *	INT	INT
16 JUN 82	all	16.8		
23 JUN 82	all	18.9	10.5	3.8
02 AUG 82	all	2.4	1.1	0.9
26 AUG 82	all	2.6	3.2	2.4
28 SEP 82	all	2.6	2.4	1.8
		INT	INT	INT
16 JUN 82	Urea (Inc.)	17.8 de		
16 JUN 82	Urea (Surf.)	15.2 d		
23 JUN 82	Zero-N	3.7 abc	4.0 ab	1.1 a
23 JUN 82	Urea (Inc.)	19.9 e	7.9 b	4.0 c
23 JUN 82	Urea (Surf.)	33.1 f	19.7 c	6.1 d
02 AUG 82	Zero-N	0.0 a	0.3 a	0.6 a
02 AUG 82	Urea (Inc.)	0.7 ab	0.7 a	0.7 a
02 AUG 82	Urea (Surf.)	5.7 c	2.1 ab	1.3 a
26 AUG 82	Zero-N	1.8 abc	4.6 ab	3.1 bc
26 AUG 82	Urea (Inc.)	2.4 abc	2.3 ab	2.2 ab
26 AUG 82	Urea (Surf.)	3.8 abc	3.0 ab	2.1 ab
28 SEP 82	Zero-N	1.2 ab	1.8 ab	1.8 ab
28 SEP 82	Urea (Inc.)	2.4 abc	1.9 ab	1.6 ab
28 SEP 82	Urea (Surf.)	4.2 bc	3.3 ab	1.9 ab
	BLSD	4.1	6.4	1.6
1983 NO_3^--N Concentration (μg/g)				
all	Zero-N	1.2	1.2	4.3
all	Urea (Inc.)	3.5	0.9	0.8
all	Urea (Surf.)	4.4	2.0	1.3
	BLSD	INT	NS	NS
20 MAY 83	all	4.4	2.2 b	3.1
28 JUN 83	all	4.5	1.5 ab	1.0
22 JUL 83	all	0.8	0.3 a	2.2
	BLSD	INT	1.6	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 NO_3^--N Concentration (µg/g)				
20 MAY 83	Zero-N	3.4 bc	1.1	6.6
20 MAY 83	Urea (Inc.)	4.0 c	1.6	0.9
20 MAY 83	Urea (Surf.)	5.3 cd	4.3	1.8
28 JUN 83	Zero-N	0.8 a	2.2	0.7
28 JUN 83	Urea (Inc.)	5.7 cd	1.0	1.1
28 JUN 83	Urea (Surf.)	7.5 d	1.4	1.2
22 JUL 83	Zero-N	0.3 a	0.4	5.0
22 JUL 83	Urea (Inc.)	0.8 a	0.1	0.5
22 JUL 83	Urea (Surf.)	1.2 ab	0.3	0.9
	BLSD	2.3	NS	NS
1984 NO_3^--N Concentration (µg/g)				
all	Zero-N	1.5	0.3 a	1.0
all	Urea (Inc.)	6.0	1.3 b	0.7
all	Urea (Surf.)	7.1	1.1 ab	0.9
		INT *	0.8	NS
18 MAY 84	all	6.4		
31 MAY 84	all	12.3	2.0 b	2.0
28 JUN 84	all	7.8	1.9 b	0.8
25 JUL 84	all	0.8	0.3 a	0.6
22 AUG 84	all	0.6	0.3 a	0.5
18 SEP 84	all	1.8	0.3 a	0.4
	BLSD	INT	1.0	NS
18 MAY 84	Zero-N	3.3 ab		
18 MAY 84	Urea (Inc.)	7.2 cd		
18 MAY 84	Urea (Surf.)	8.6 d		
31 MAY 84	Zero-N	5.0 bc	0.7	2.9
31 MAY 84	Urea (Inc.)	16.4 e	4.3	1.5
31 MAY 84	Urea (Surf.)	14.0 e	1.5	1.7
28 JUN 84	Zero-N	0.4 a	0.7	0.9
28 JUN 84	Urea (Inc.)	7.4 cd	2.0	0.6
28 JUN 84	Urea (Surf.)	15.5 e	2.7	0.8
25 JUL 84	Zero-N	0.1 a	0.1	0.4
25 JUL 84	Urea (Inc.)	0.8 a	0.3	0.6
25 JUL 84	Urea (Surf.)	1.4 a	0.4	0.8
22 AUG 84	Zero-N	0.2 a	0.0	0.2
22 AUG 84	Urea (Inc.)	0.6 a	0.3	0.5
22 AUG 84	Urea (Surf.)	0.9 a	0.6	0.7
18 SEP 84	Zero-N	0.5 a	0.3	0.5
18 SEP 84	Urea (Inc.)	2.6 ab	0.3	0.2
18 SEP 84	Urea (Surf.)	2.4 ab	0.3	0.5
	BLSD	3.6	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 Atom % ^{15}N in NO_3^- form				
all	Zero-N	0.443 a *		
all	Urea (Inc.)	1.170 b		
all	Urea (Surf.)	1.102 b		
	BLSD	0.235		
16 JUN 82	all	1.496 b		
23 JUN 82	all	2.053 c		
02 AUG 82	all	0.707 a		
26 AUG 82	all	0.556 a		
28 SEP 82	all	0.587 a		
	BLSD	0.394		
16 JUN 82	Urea (Inc.)	1.747		
16 JUN 82	Urea (Surf.)	1.182		
23 JUN 82	Zero-N			
23 JUN 82	Urea (Inc.)	2.080		
23 JUN 82	Urea (Surf.)	2.027		
02 AUG 82	Zero-N	0.533		
02 AUG 82	Urea (Inc.)	0.721		
02 AUG 82	Urea (Surf.)	0.797		
26 AUG 82	Zero-N	0.404		
26 AUG 82	Urea (Inc.)	0.519		
26 AUG 82	Urea (Surf.)	0.791		
28 SEP 82	Zero-N	0.427		
28 SEP 82	Urea (Inc.)	0.685		
28 SEP 82	Urea (Surf.)	0.668		
		NS		
1983 Atom % ^{15}N in NO_3^- form				
all	Zero-N	0.512		
all	Urea (Inc.)	1.161		
all	Urea (Surf.)	1.364		
		INT		
20 MAY 83	all	1.246		
23 JUN 83	all	1.343		
22 JUL 83	all	0.691		
		INT		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 Atom % ^{15}N in NO_3^- form				
20 MAY 83	Zero-N			
20 MAY 83	Urea (Inc.)	1.066 bc *		
20 MAY 83	Urea (Surf.)	1.426 cd		
28 JUN 83	Zero-N	0.470 a		
28 JUN 83	Urea (Inc.)	1.623 d		
28 JUN 83	Urea (Surf.)	2.085 e		
22 JUL 83	Zero-N	0.553 a		
22 JUL 83	Urea (Inc.)	0.795 ab		
22 JUL 83	Urea (Surf.)	0.725 ab		
	BLSD	0.440		
1984 Atom % ^{15}N in NO_3^- form				
all	Zero-N	0.563		
all	Urea (Inc.)	1.495		
all	Urea (Surf.)	1.623		
		INT		
18 MAY 84	all	1.687		
31 MAY 84	all	1.709		
28 JUN 84	all	1.261		
25 JUL 84	all	0.679		
22 AUG 84	all	1.312		
18 SEP 84	all	0.737		
		INT		
18 MAY 84	Zero-N	0.463 a		
18 MAY 84	Urea (Inc.)	1.900 cd		
18 MAY 84	Urea (Surf.)	2.699 d		
31 MAY 84	Zero-N	0.597 ab		
31 MAY 84	Urea (Inc.)	2.211 cd		
31 MAY 84	Urea (Surf.)	2.098 cd		
28 JUN 84	Zero-N	0.572 ab		
28 JUN 84	Urea (Inc.)	1.284 abc		
28 JUN 84	Urea (Surf.)	1.927 cd		
25 JUL 84	Zero-N	0.523 ab		
25 JUL 84	Urea (Inc.)	0.768 ab		
25 JUL 84	Urea (Surf.)	0.746 ab		
22 AUG 84	Zero-N	0.666 ab		
22 AUG 84	Urea (Inc.)	1.830 cd		
22 AUG 84	Urea (Surf.)	1.439 bc		
18 SEP 84	Zero-N			
18 SEP 84	Urea (Inc.)	0.844 ab		
18 SEP 84	Urea (Surf.)	0.630 ab		
	BLSD	0.940		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 NO_3^--N from fertilizer source (kg/ha)				
all	Urea (Inc.)	4.2		
all	Urea (Surf.)	4.9		
		NS *		
16 JUN 82	all	5.4 a		
23 JUN 82	all	14.8 b		
02 AUG 82	all	0.8 a		
26 AUG 82	all	0.4 a		
28 SEP 82	all	0.5 a		
	BLSD	6.6		
16 JUN 82	Urea (Inc.)	7.2		
16 JUN 82	Urea (Surf.)	3.2		
23 JUN 82	Urea (Inc.)	12.4		
23 JUN 82	Urea (Surf.)	17.2		
02 AUG 82	Urea (Inc.)	0.1		
02 AUG 82	Urea (Surf.)	1.5		
26 AUG 82	Urea (Inc.)	0.1		
26 AUG 82	Urea (Surf.)	0.7		
28 SEP 82	Urea (Inc.)	0.3		
28 SEP 82	Urea (Surf.)	0.6		
		NS		
1983 NO_3^--N from fertilizer source (kg/ha)				
all	Urea (Inc.)	1.3		
all	Urea (Surf.)	2.3		
		NS		
20 MAY 83	all	1.4 ab		
28 JUN 83	all	3.9 b		
22 JUL 83	all	0.1 a		
	BLSD	2.6		
20 MAY 83	Urea (Inc.)	0.9		
20 MAY 83	Urea (Surf.)	1.8		
28 JUN 83	Urea (Inc.)	2.7		
28 JUN 83	Urea (Surf.)	5.0		
22 JUL 83	Urea (Inc.)	0.1		
22 JUL 83	Urea (Surf.)	0.1		
		NS		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1984 NO_3^--N from fertilizer source (kg/ha)				
all	Urea (Inc.)	2.7		
all	Urea (Surf.)	4.1		
		NS *		
18 MAY 84	all	4.9 bc		
31 MAY 84	all	8.7 c		
28 JUN 84	all	5.9 c		
25 JUL 84	all	0.2 a		
22 AUG 84	all	0.3 ab		
18 SEP 84	all	0.3 ab		
	BLSD	4.7		
18 MAY 84	Urea (Inc.)	3.4		
18 MAY 84	Urea (Surf.)	6.4		
31 MAY 84	Urea (Inc.)	9.6		
31 MAY 84	Urea (Surf.)	7.8		
28 JUN 84	Urea (Inc.)	2.4		
28 JUN 84	Urea (Surf.)	9.4		
25 JUL 84	Urea (Inc.)	0.1		
25 JUL 84	Urea (Surf.)	0.2		
22 AUG 84	Urea (Inc.)	0.2		
22 AUG 84	Urea (Surf.)	0.3		
18 SEP 84	Urea (Inc.)	0.4		
18 SEP 84	Urea (Surf.)	0.2		
		NS		

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 Total N Concentration (µg/g)				
all	Zero-N	1659.2	1030.9	525.7
all	Urea (Inc.)	1782.2	851.4	448.3
all	Urea (Surf.)	2039.5	936.6	498.0
		NS *	NS	NS
16 JUN 82	all	1967.9		
23 JUN 82	all	1933.3	532.3 a	465.5
02 AUG 82	all	1801.6	1045.6 b	470.1
26 AUG 82	all	1774.8	1062.0 b	495.6
28 SEP 82	all	1755.0	1149.6 b	527.4
	BLSD	NS	194.4	NS
16 JUN 82	Urea (Inc.)	1885.6		
16 JUN 82	Urea (Surf.)	2070.7		
23 JUN 82	Zero-N	1573.6	494.5	481.1
23 JUN 82	Urea (Inc.)	1927.3	491.9	421.6
23 JUN 82	Urea (Surf.)	2298.9	610.7	493.8
02 AUG 82	Zero-N	1983.1	1309.0	521.2
02 AUG 82	Urea (Inc.)	1602.9	947.2	464.2
02 AUG 82	Urea (Surf.)	1891.4	971.1	445.4
26 AUG 82	Zero-N	1571.4	1312.5	532.3
26 AUG 82	Urea (Inc.)	1719.9	992.9	483.2
26 AUG 82	Urea (Surf.)	2097.8	930.6	478.6
28 SEP 82	Zero-N	1638.4	1175.1	578.1
28 SEP 82	Urea (Inc.)	1773.9	1004.0	418.2
28 SEP 82	Urea (Surf.)	1856.5	1240.8	574.3
		NS	NS	NS
1983 Total N Concentration (µg/g)				
all	Zero-N	1479.6	784.1	594.4
all	Urea (Inc.)	1559.8	544.5	214.1
all	Urea (Surf.)	2070.1	816.5	367.0
		NS	NS	NS
20 MAY 83	all	1779.4 b	778.3	357.1
28 JUN 83	all	1754.5 b	712.6	247.7
22 JUL 83	all	1594.5 a	640.0	560.5
	BLSD	111.8	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 Total N Concentration (μg/g)				
20 MAY 83	Zero-N	1567.8	803.6	510.0
20 MAY 83	Urea (Inc.)	1626.2	636.1	197.8
20 MAY 83	Urea (Surf.)	2059.5	924.3	363.4
28 JUN 83	Zero-N	1505.9	936.4	268.9
28 JUN 83	Urea (Inc.)	1557.2	453.3	159.3
28 JUN 83	Urea (Surf.)	2311.9	747.9	319.1
22 JUL 83	Zero-N	1400.5	612.3	939.2
22 JUL 83	Urea (Inc.)	1496.0	544.1	285.2
22 JUL 83	Urea (Surf.)	1887.1	794.4	431.2
		NS *	NS	NS
1984 Total N Concentration (μg/g)				
all	Zero-N	1408.2	952.4	488.0
all	Urea (Inc.)	1694.0	989.0	266.8
all	Urea (Surf.)	2007.7	1176.8	389.1
		NS	NS	NS
18 MAY 84	all	1691.0		
31 MAY 84	all	1683.5	941.5 ab	484.3
28 JUN 84	all	1705.3	1252.2 d	390.0
25 JUL 84	all	1692.3	1011.3 bc	323.1
22 AUG 84	all	1695.4	778.2 a	319.4
18 SEP 84	all	1825.5	1230.7 cd	369.5
	BLSD	NS	228.0	NS
18 MAY 84	Zero-N	1503.2		
18 MAY 84	Urea (Inc.)	1638.9		
18 MAY 84	Urea (Surf.)	1931.0		
31 MAY 84	Zero-N	1281.1	914.5	948.6
31 MAY 84	Urea (Inc.)	1546.4	706.0	188.8
31 MAY 84	Urea (Surf.)	2061.9	1156.8	315.5
28 JUN 84	Zero-N	1315.5	1152.4	511.6
28 JUN 84	Urea (Inc.)	1791.5	1299.2	263.4
28 JUN 84	Urea (Surf.)	2009.0	1285.0	394.9
25 JUL 84	Zero-N	1261.3	1015.4	347.4
25 JUL 84	Urea (Inc.)	1749.0	945.5	267.6
25 JUL 84	Urea (Surf.)	2066.6	1072.9	354.3
22 AUG 84	Zero-N	1451.9	679.3	254.4
22 AUG 84	Urea (Inc.)	1648.8	629.3	311.6
22 AUG 84	Urea (Surf.)	1985.5	1026.0	379.1
18 SEP 84	Zero-N	1629.7	1040.2	226.5
18 SEP 84	Urea (Inc.)	1813.2	1308.5	311.3
18 SEP 84	Urea (Surf.)	1991.9	1343.3	501.9
		NS	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 Atom % ^{15}N in Total N				
all	Zero-N	0.368	0.369 a *	0.375
all	Urea (Inc.)	0.463	0.393 b	0.404
all	Urea (Surf.)	0.458	0.388 b	0.395
	BLSD	INT	0.015	NS
16 JUN 82	all	0.518		
23 JUN 82	all	0.466	0.390	0.398
02 AUG 82	all	0.406	0.377	0.402
26 AUG 82	all	0.407	0.385	0.396
28 SEP 82	all	0.402	0.381	0.372
		INT	NS	NS
16 JUN 82	Urea (Inc.)	0.514 de		
16 JUN 82	Urea (Surf.)	0.524 de		
23 JUN 82	Zero-N	0.372 a	0.373	0.371
23 JUN 82	Urea (Inc.)	0.475 cd	0.394	0.417
23 JUN 82	Urea (Surf.)	0.549 e	0.402	0.405
02 AUG 82	Zero-N	0.371 a	0.361	0.377
02 AUG 82	Urea (Inc.)	0.438 bc	0.386	0.420
02 AUG 82	Urea (Surf.)	0.395 ab	0.378	0.400
26 AUG 82	Zero-N	0.365 a	0.374	0.385
26 AUG 82	Urea (Inc.)	0.436 bc	0.393	0.400
26 AUG 82	Urea (Surf.)	0.422 abc	0.384	0.402
28 SEP 82	Zero-N	0.363 a	0.367	0.368
28 SEP 82	Urea (Inc.)	0.447 bc	0.400	0.374
28 SEP 82	Urea (Surf.)	0.403 ab	0.384	0.374
	BLSD	0.062	NS	NS
1983 Atom % ^{15}N in Total N				
all	Zero-N	0.371	0.373 a	0.378 a
all	Urea (Inc.)	0.485	0.406 b	0.414 b
all	Urea (Surf.)	0.516	0.378 a	0.411 b
	BLSD	INT	0.017	.033
20 MAY 83	all	0.531	0.375	0.380 a
28 JUN 83	all	0.430	0.392	0.440 b
22 JUL 83	all	0.420	0.390	0.387 a
		INT	NS	0.039

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 Atom % ^{15}N in Total N				
20 MAY 83	Zero-N	0.363 a *	0.366	0.372
20 MAY 83	Urea (Inc.)	0.542 d	0.383	0.385
20 MAY 83	Urea (Surf.)	0.622 e	0.377	0.382
28 JUN 83	Zero-N	0.373 ab	0.372	0.389
28 JUN 83	Urea (Inc.)	0.461 c	0.405	0.464
28 JUN 83	Urea (Surf.)	0.472 c	0.400	0.456
22 JUL 83	Zero-N	0.373 ab	0.382	0.375
22 JUL 83	Urea (Inc.)	0.453 c	0.428	0.394
22 JUL 83	Urea (Surf.)	0.436 bc	0.353	0.393
	BLSD	0.065	NS	NS
1984 Atom % ^{15}N in Total N				
all	Zero-N	0.375	0.375	0.368
all	Urea (Inc.)	0.476	0.375	0.410
all	Urea (Surf.)	0.499	0.377	0.419
		INT	NS	NS
18 MAY 84	all	0.546		
31 MAY 84	all	0.497	0.388 d	0.423
28 JUN 84	all	0.427	0.374 b	0.386
25 JUL 84	all	0.420	0.370 ab	0.385
22 AUG 84	all	0.404	0.382 c	0.443
18 SEP 84	all	0.412	0.368 a	0.365
		INT	0.005	NS
18 MAY 84	Zero-N	0.372 a		
18 MAY 84	Urea (Inc.)	0.603 e		
18 MAY 84	Urea (Surf.)	0.665 f		
31 MAY 84	Zero-N	0.379 ab	0.384	0.376
31 MAY 84	Urea (Inc.)	0.492 d	0.385	0.438
31 MAY 84	Urea (Surf.)	0.596 e	0.393	0.455
28 JUN 84	Zero-N	0.374 ab	0.379	0.378
28 JUN 84	Urea (Inc.)	0.447 cd	0.371	0.385
28 JUN 84	Urea (Surf.)	0.460 cd	0.374	0.395
25 JUL 84	Zero-N	0.372 a	0.367	0.376
25 JUL 84	Urea (Inc.)	0.453 cd	0.372	0.391
25 JUL 84	Urea (Surf.)	0.434 c	0.370	0.388
22 AUG 84	Zero-N	0.374 ab	0.383	0.406
22 AUG 84	Urea (Inc.)	0.414 abc	0.382	0.432
22 AUG 84	Urea (Surf.)	0.425 bc	0.381	0.475
18 SEP 84	Zero-N	0.381 ab	0.365	0.288
18 SEP 84	Urea (Inc.)	0.439 c	0.370	0.399
18 SEP 84	Urea (Surf.)	0.416 abc	0.368	0.384
	BLSD	0.051	NS	NS

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1982 Total N from Fertilizer Source (kg/ha)				
all	Urea (Inc.)	52.2	5.5	5.9
all	Urea (Surf.)	55.6	5.3	4.3
	BLSD	NS *	NS	NS
16 JUN 82	all	89.4 b		
23 JUN 82	all	95.2 b	4.8	8.2
02 AUG 82	all	22.4 a	3.0	5.6
26 AUG 82	all	35.4 a	6.3	5.1
28 SEP 82	all	27.8 a	7.4	1.0
	BLSD	36.4	NS	NS
16 JUN 82	Urea (Inc.)	87.4		
16 JUN 82	Urea (Surf.)	92.0		
23 JUN 82	Urea (Inc.)	64.7	2.8	9.0
23 JUN 82	Urea (Surf.)	125.6	6.8	7.4
02 AUG 82	Urea (Inc.)	31.2	3.8	7.0
02 AUG 82	Urea (Surf.)	13.7	2.0	4.2
26 AUG 82	Urea (Inc.)	33.8	8.2	5.8
26 AUG 82	Urea (Surf.)	37.1	4.4	4.4
28 SEP 82	Urea (Inc.)	41.7	7.5	0.6
28 SEP 82	Urea (Surf.)	16.7	7.3	1.3
	BLSD	NS	NS	NS
1983 Total N from Fertilizer Source (kg/ha)				
all	Urea (Inc.)	53.6	3.9 a	3.6
all	Urea (Surf.)	87.8	5.9 b	5.4
		INT		NS
20 MAY 83	all	115.9	2.0 a	1.0 a
28 JUN 83	all	58.8	6.1 b	9.5 b
22 JUL 83	all	34.4	6.1 b	2.8 a
	BLSD	INT	1.84	6.6

- Continued -

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 21 Continued. Mean separations of soil nitrogen concentrations in ^{15}N plots.

Sampling Date	Fertilizer Treatment	0-15 cm Depth	15-30 cm Depth	30-45 cm Depth
1983 Total N from Fertilizer Source (kg/ha)				
20 MAY 83	Urea (Inc.)	84.6 b *	2.5	0.9
20 MAY 83	Urea (Surf.)	147.2 c	1.3	1.0
28 JUN 83	Urea (Inc.)	41.3 a	4.6	7.6
28 JUN 83	Urea (Surf.)	80.8 b	7.7	11.4
22 JUL 83	Urea (Inc.)	34.9 a	4.6	2.3
22 JUL 83	Urea (Surf.)	33.9 a	7.7	3.3
	BLSD	28.7	NS	NS
1984 Total N from Fertilizer Source (kg/ha)				
all	Urea (Inc.)	51.4	1.4	3.8
all	Urea (Surf.)	76.7	2.7	5.5
		INT	NS	NS
18 MAY 84	all	145.4		
31 MAY 84	all	96.8	7.4 b	7.7
28 JUN 84	all	48.6	0.5 a	2.8
25 JUL 84	all	40.7	0.4 a	2.0
22 AUG 84	all	24.7	1.9 a	8.2
18 SEP 84	all	28.4	0.1 a	2.8
	BLSD	INT	2.9	NS
18 MAY 84	Urea (Inc.)	115.2 d		
18 MAY 84	Urea (Surf.)	175.6 e		
31 MAY 84	Urea (Inc.)	56.6 c	4.2	5.8
31 MAY 84	Urea (Surf.)	137.0 d	10.6	9.6
28 JUN 84	Urea (Inc.)	42.9 abc	0.3	1.3
28 JUN 84	Urea (Surf.)	54.4 bc	0.8	4.2
25 JUL 84	Urea (Inc.)	41.8 abc	0.8	1.9
25 JUL 84	Urea (Surf.)	39.6 abc	0.0	2.2
22 AUG 84	Urea (Inc.)	20.3 a	1.5	6.9
22 AUG 84	Urea (Surf.)	29.0 abc	2.2	9.4
18 SEP 84	Urea (Inc.)	32.0 abc	0.2	3.3
18 SEP 84	Urea (Surf.)	22.3 ab	0.0	2.2
	BLSD	30.2	NS	NS

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test (BLSD). NS indicates not significant. INT indicates a significant interaction.

Table 22. ANOVA tables of grain yields.

Source	df	SS	MS	F
1982				
Block (B)	4	802127	200532	1.00
Fertilizer Treatment (F)	5	2075350	415070	2.06
BxF (error)	20	4027165	201358	
1983				
Block (B)	4	498363	124591	0.48
Fertilizer Treatmnt (F)	5	46808959	9361792	36.36 *
BxF (error)	20	5150090	257505	
1984				
Block (B)	4	100098	25024	0.36
Fertilizer Treatment (F)	5	38478012	7695602	110.99 *
BxF (error)	20	1386754	69338	

* Significant at the 5% level of probability.

Table 23. Mean separations of grain yields.

Fertilizer Treatment		1982 (kg/ha)	1983 (kg/ha)	1984 (kg/ha)
Zero-N	Incorporated	2099	625 a *	1233 a
Zero-N	Surface applied	2404	1034 a	1487 a
$Ca(NO_3)_2$	Incorporated	2549	3667 b	3640 bc
$Ca(NO_3)_2$	Surface applied	2438	3317 b	3863 c
Urea	Incorporated	2954	3495 b	3514 b
Urea	Surface applied	2689	3346 b	3940 c
	BLSD	NS	610	313

* Means followed by the same letter in each column are not significantly different at the 5% level of probability by Waller and Duncan's Bayes Least Significant Difference test. NS indicates not significant.